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MAGAZINE
January 2013

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- ◆ Modular Mobots For STEM
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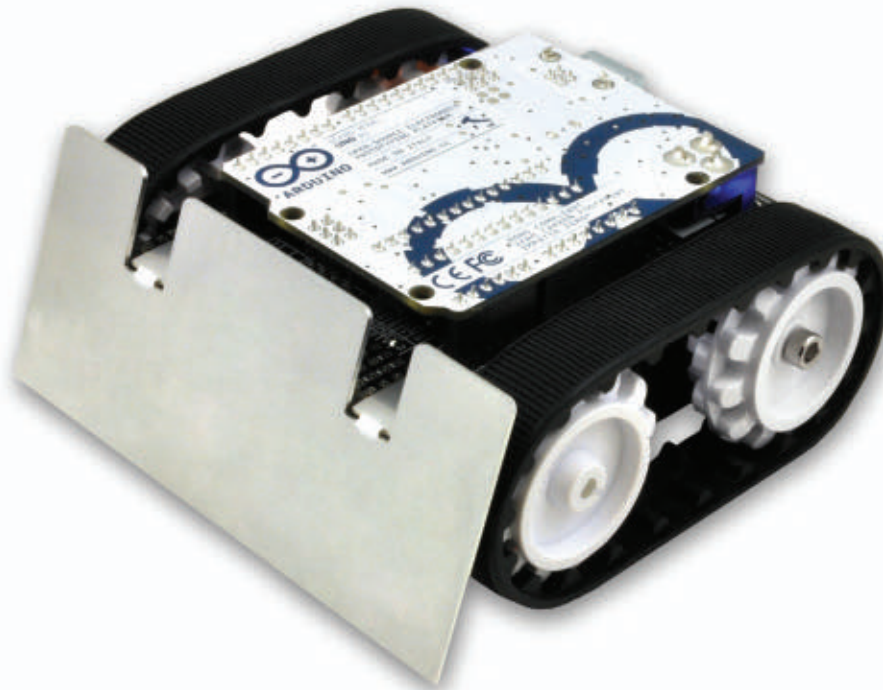


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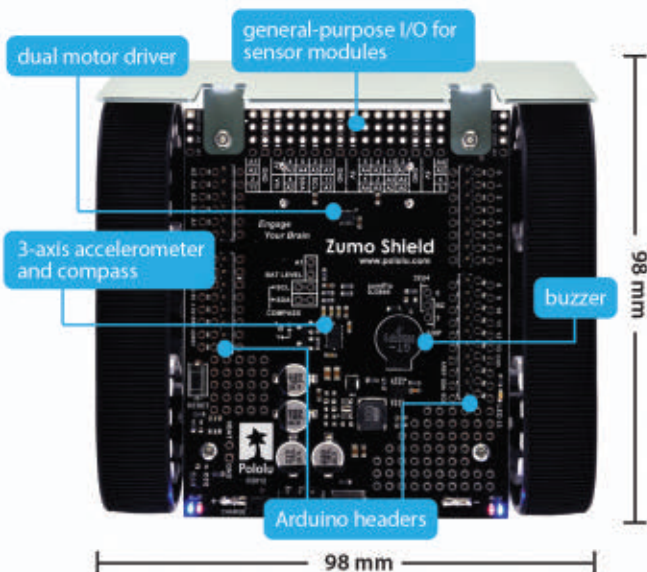
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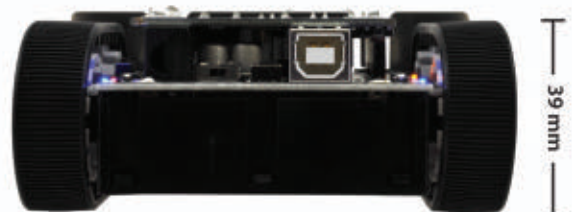


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NEW!
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now available!
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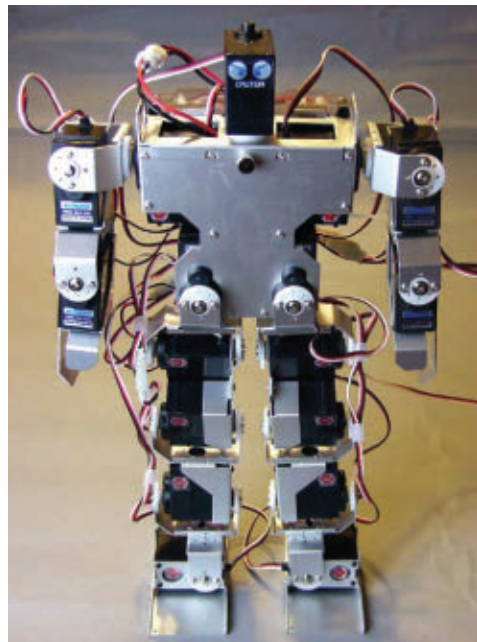
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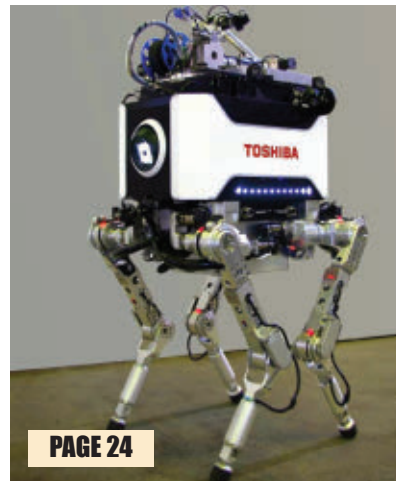
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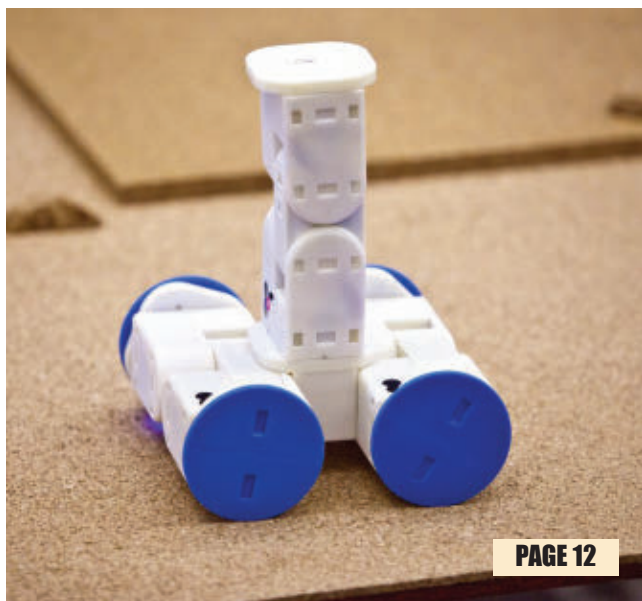
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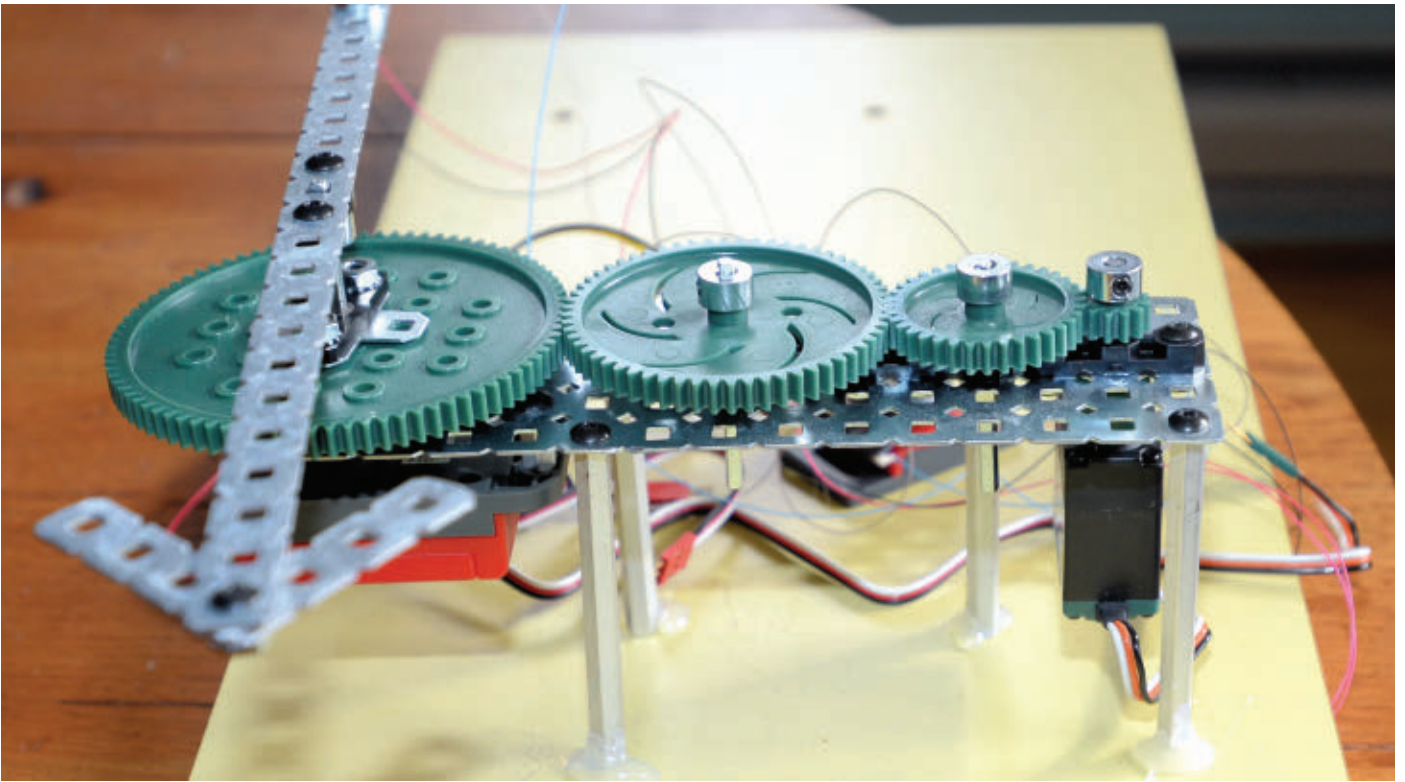


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38 Go Mod With Your Mobile

by Fred Eady

What do you get when you give your robot a GPS module, a microSD card, and a temperature probe? A robot who knows where it's going and can tell you where it's been. Depending on where your robot is or is going, it may be wrapped up in an overcoat or sporting a Hawaiian shirt.

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Mind / Iron

by Bryan Bergeron, Editor

Cutting Corners

Experimenting with robotics — for the most of us — is a 'nice to have' activity that is stimulating, challenging, and rewarding on several fronts. Unless you're fortunate enough to work with robotics as a career, components and platforms are not a 'must have' when the end of the month rolls around and it's time to budget expenses for your next project. So, it's tempting to cut corners here and there in order to stretch available funds. However, there's a limit to cutting because at some point, you'll limit the possible success of your project.

For example, I just finished assembling a robotic arm and mobile platform that I purchased from an established robotics company. I had picked up the equivalent earlier model before the economic downturn, so my expectations of build quality and components were set by that experience. In short, I was disappointed.

Starting from the user interface, instead of using set-screw knobs with D-shaft pots, the pots featured smooth round shafts. Within minutes of working the robot arm controls, the knobs began to slip. I suppose the D-shaft pots might have cost the manufacturer a few cents more than the round shaft version, but at the expense of a workable user interface. I flattened the shafts with a Dremel and reattached the knobs. The knobs are now workable with no detectable play.

Then, there's the base of the arm controller. It was nicely painted with smoothed corners, but unlike the previous model there were no rubber feet. At best, the unit slides around on a hard tabletop. At worst, it mars the finish of a wooden tabletop. Self-adhesive rubber feet were an inexpensive but bothersome fix.

Moving inside the arm and controller unit, I noticed that the power supply components were lacking the thermal grease that was used in the previous model. It probably takes a few more seconds to assemble the unit when messy thermal grease is used, and labor is undoubtedly expensive these days. The downside, of course, is that the temperature of the power supply components is greater, and component life suffers.

Another disconcerting shortcut was the wiring. Several of the 16 gauge connections from the power supply had been replaced with more diminutive 24 gauge wires. Worse yet — from a maintenance perspective — the power supply connectors were replaced by direct connections.

The main point in all of this is that cutting corners is a natural reflex to the increasing cost of components and limited resources. However, you have to know what to cut and what to leave as-is. In the examples above, the mismatched shaft and knob could have been a constant annoyance, but wouldn't have resulted in catastrophic failure. The lack of rubber feet is more problematic, especially if they prevent you from scarring the kitchen table. Failing to use thermal grease when it's clearly called for is simply unconscionable. Why not invest in a few dollops of grease today to double or perhaps triple the life expectancy of a component?

Skimping on wire gauge and connectors seems almost as egregious, depending on the average and peak current drawn by the servos in the robot arm. You don't want to endanger lives by creating a fire hazard.

It's a good idea to have a 'no cut' list that contains the components and accessories that shouldn't be subject to skimping. And it should be adaptable to context. For example, skimping on lock washers may be okay for a carpet crawler, but not for a four pound quadcopter that could come smashing down with the loss of a nut. The best way to cut back on a complex system, of course, is to simplify the design. Engineer out what you don't need and take some of the savings and invest them in higher quality components, cables, and connectors. **SV**

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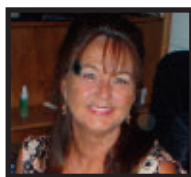
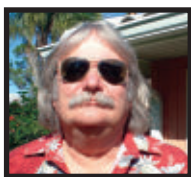
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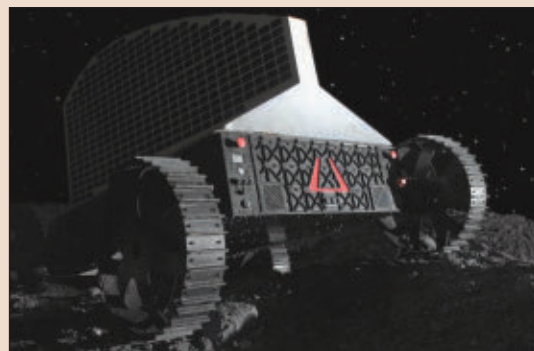


Don't Forget the Moon

If you have been caught up in the wave of news coming from the Martian surface, you may not have noticed that there are still some interesting things going on with our old friend, the moon. In fact, back in 2009, it was confirmed that rather than being just a solid chunk of rock, the moon actually has lots of underground caves created when lava flows drained away and left long tunnels behind. In 2011, India's space agency announced the discovery of a huge volcanic cave that's more than a mile long and nearly 400 feet wide — big enough to house a small human settlement. A nice feature of such caves is that they are relatively stable in temperature, unlike the surface. Some can also be accessed through

recently discovered "skylights" (partial ceiling collapses). The bottom line is that subsurface lunar exploration is obviously a job for robots, and Astrobotic Technology (www.astrobotictech.com) recently announced completion of Polaris — a prototype lunar prospecting rover that's built for it.

The caves will have to wait a while, though, as Polaris' first assignment will be to search the moon's poles for "water, oxygen, methane, and other volatiles which could be useful for energy, supporting life, and producing rocket fuel." The moonbot is pretty hefty weighing in at 150 kg (330 lb), and it can carry about 70 kg (150 lb) of appropriate



Prototype of Polaris, a new subsurface lunar explorer.

equipment. The prototype is fitted with drilling equipment that can drive a four foot drill bit into the surface using 250W of solar generated power. According to Astrobotic, "It's game changing for lunar surface exploration, and we're the ones to pursue it." The company has won nine lunar contracts from NASA, worth \$3.6 million.

Bot Programming for Bio Labs

If you happen to work in a biological lab doing things like constructing and cloning DNA molecules, it would be pretty nice to use robots to perform labor-intensive, multistep processes for you thereby reducing your workload, lowering error rates, and increasing the reliability of experimental data. Unfortunately, automation companies "have targeted the highly repetitive industrial laboratory operations market while largely ignoring the development of flexible easy-to-use programming tools for dynamic non-repetitive research environments. As a consequence, researchers in the biological sciences have had to depend upon professional programmers or vendor-supplied graphical user interfaces with limited capabilities." This according to Nathan Hillson, a biochemist at the Department of Energy's Joint BioEnergy Institute. Therefore, Mr. Hillson led the development of PaR-PaR, which not only stands for "programming a robot" but is annoyingly awkward to type. It is basically a high-level, bio-oriented language aimed at improving the

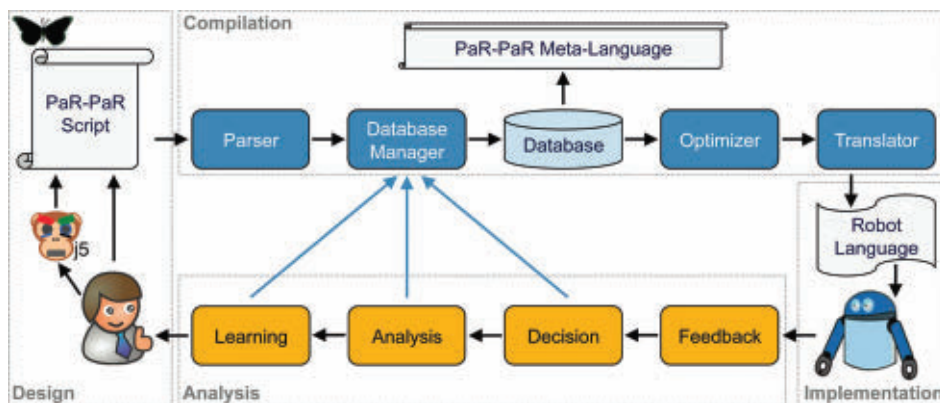


Illustration of the PaR-PaR programming language.

functionality of liquid-handling robots.

"The syntax and compiler for PaR-PaR are based on computer science principles and a deep understanding of biological workflows," Hillson said. "After minimal training, a biologist should be able to independently write complicated protocols for a robot within an hour. With the adoption of PaR-PaR as a standard cross-platform language, handwritten or software generated robotic protocols could easily be shared across laboratories." PaR-PaR is an open source program, so if you're interested, feel free to download it on the public server at parpar.jbei.org.

It's the Berries

A few years ago, the folks at the California Strawberry Commission (www.calstrawberry.com) were inspired by the concept of driverless cars, which now cruise experimentally on California highways. They reasoned that if a car can navigate miles and miles of winding roads, surely a robotic vehicle could be devised to travel through a field and pick fruits and vegetables. So, in 2007, they got together with some researchers at UCLA, Caltech, and Cornell, and put together Robotic Harvesting LLC. The result is "a highly intelligent, self-navigating robotic harvester capable of automatically picking strawberries." The system has four elements: the robotic strawberry harvester itself, a strawberry data collector (a unit that takes photos to analyze berry size, plant pathogens, and other items of interest), a stereovision system used by the data collector, and a mobile platform used for harvesting, planting, spraying, and so on. Reportedly, the system can identify berries at the proper level of ripeness and pick them at rates of somewhere between two and five seconds each. The cost of the system was not specified, but it is said to be "economical," and interested parties are invited to contact the company for a free evaluation. Of course, videos are available at www.roboticharvesting.com/videos.html.



Robotic Circus ... Maybe

Last and certainly least in our robotics review is the Electric Animal Circus — a live show under development by Patrick Gleeson, a London-based, self-described "composer/coder/maker." He is not to be confused with the musician, synthesizer pioneer, composer, and producer from San Francisco of the same name. The Brit is in the process of assembling a traveling show that includes live original music performed on "strange made-up instruments," concept art, odd costumes and — of course — an assemblage of robotic animals. He recently announced completion of the first phase which seems to consist of settling on the concept. What is needed to move from a concept in a shed somewhere to the big time? "Well," he explained, "Now we need to actually create the show we've been talking about for so long. We need to gather together in one place a group of like-minded people, and a big chunk of cash, and begin the long journey that will end, one day, in a large



An insect-like creature in the workshop awaits its chance at fame and fortune.

auditorium somewhere in the world, as the house lights dim, the crowd falls silent, the opening notes are played, and the Electric Animal Circus reveals itself to the world." If this piques your interest, drop in on www.electricanimalcircus.com and check it out. Don't miss the recording by Miss Karla Kat & Her Ticking Kittens which actually isn't as awful as you are probably expecting. Then, if you have any skills in acting, animatronics, dance, filmmaking, or any related field (or if you just have money in your checking account), hop across the pond and join the fun.

UAS Provides Sophistication, Stealth

Unmanned aerial vehicles (UAVs) come in all shapes and sizes these days, ranging from less than a pound to over 40,000 pounds. Since 2000, the US military alone has increased its inventory from about 50 to an estimated 7,000. As you may have noticed, the sophistication of UAVs has increased considerably, leading to a growing number of them being designated "unmanned aerial systems (UAS)" rather than UAVs. Toward the low end in terms of size but the high end in terms of sophistication is the Maveric UAS, produced by Priora Robotics (www.priora.com) — a Gainesville-based company founded by graduates from the University of Florida. According to the company, "Maveric can be deployed immediately with no



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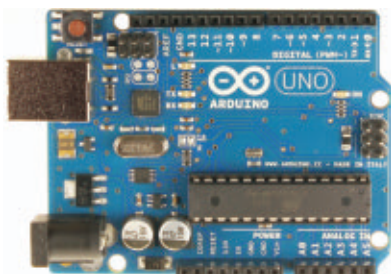


assembly, and with a dash speed of 55 knots, it delivers a rapid, eyes on-target and tracking performance. Cursor on target (CoT) compliant capabilities provide a point-and-click feature for operators to acquire and follow a target, while the unique power distribution board allows Maveric to also fly stealthy by not emitting camera RF until the operator decides."

In addition to being controlled via a joystick, Maveric is capable of autonomous operation from launch to landing. You can launch it from a tube or just give it a toss. Pertinent specs include a cruise speed of 26 kt, maximum altitude of 25,000 ft, and 45-90 min endurance – depending on configuration – with a battery recharge time of less than 30 sec. It is extremely stealthy as it is shaped like a bird and is inaudible if it's at least 100 m (328 ft) away from you. Features include a retractable gimbaled camera, onboard image processing, and a choice of eight flight modes. The company website doesn't specify a base price, but the Canadian government ordered five of them a couple years ago for use in Afghanistan coming in at about \$560,000 apiece, so you probably won't be buying one to spot stray dogs in your neighborhood. **SV**

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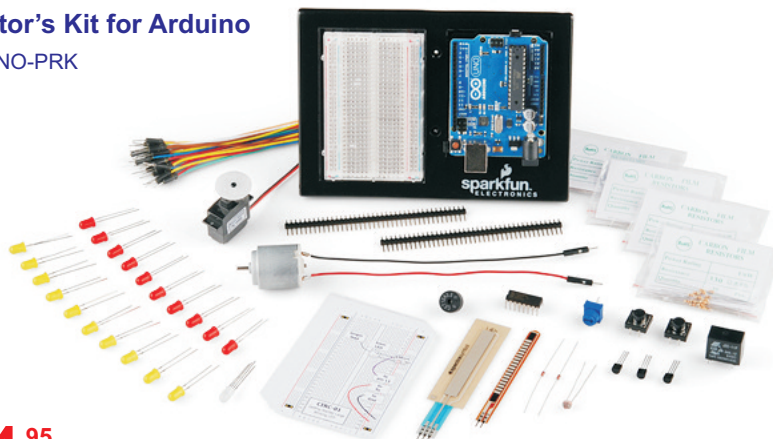
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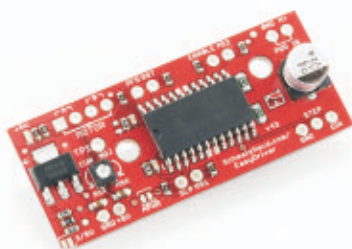
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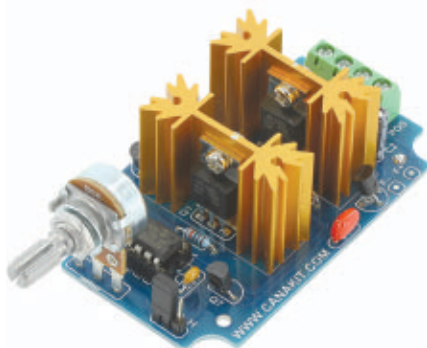
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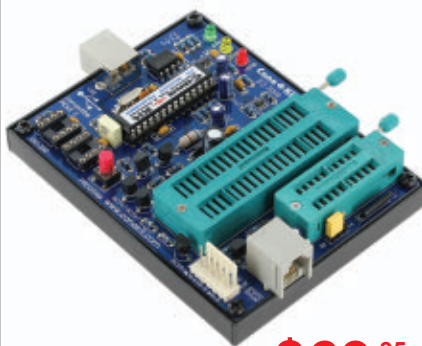
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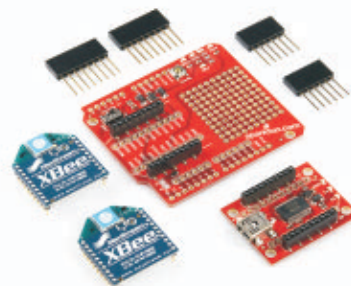
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XBEE-KIT

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GEER HEAD

by David Geer

Contact the author at geercom@windstream.net

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Modular Mobots Make STEM Education Fun



A student from
Bridgeway
Island
Elementary
School is
inspecting her
Mobot robot
configuration.

UC Davis — a 100+ year old institution of higher education — is encouraging STEM (Science, Technology, Engineering and Math) educational enhancements through the use of Mobots: a robot module platform created by Engineering Professor Harry H. Cheng and his master's student Graham Ryland. The plastic Mobots with their user-friendly programming and software are already in use in many area schools.

Let's take a look at the robot's nature, construction, modularity, technologies, and applicability to the classroom.



A Mobot modular robot configuration. The Mobots modules each have hardware interfaces that rotate, as well as joints that move. Students can connect and program a number of the modules to create various robots with multiple capabilities.

Modular Mobots

The Mobots from Professor Cheng (and now Barobo Robotics) are an entirely wireless (Bluetooth enabled) modular robotics platform offering several degrees of freedom per module which multiplies into many degrees of freedom per robot as more Mobots are added.

These simple fun modules are completely safe and easily snapped together, making them the "Tinker toys" of educational robots, so to speak. Students apply math, engineering, and programming skills to configure the modules into robots that demonstrate the practical motion and interaction capabilities of the platform.

While the modules can stand up to heavy classroom use, they are constrained from causing harm by software that innately eliminates risky collisions and movements. Students can interact with the robots physically and up close while programming them or actually running their programs.

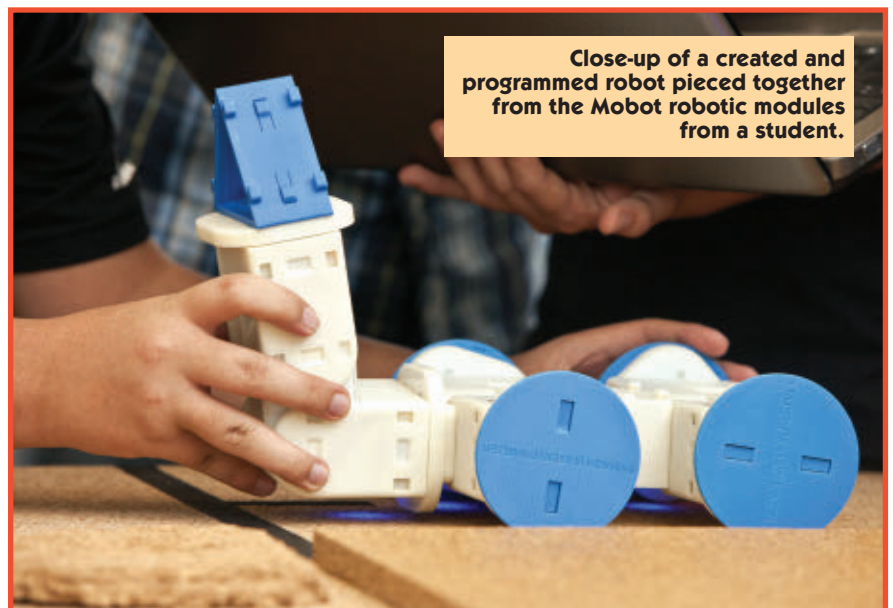
The K-12 STEM education platform consists of individual Mobot modules, each with four degrees of freedom plus their add-ons. Each module can stand, crawl, turn, roll and tumble, connect to other modules, and turn attachable wheels and parts. Mobots create 4 x 4 trucks, snakes, dogs, humanoids, or anything a student can imagine within the scope of any combination of modules.

The Mobot modules are individually programmable, and connected Mobots are simultaneously controlled by their

programming via Bluetooth as mentioned. The platform requires only a laptop or computer with Bluetooth. The modules never require external wires. All the modules run on two rechargeable 9V batteries which are included. These give each module two hours of battery life.

The four degrees of freedom in the modules consist of two body joints and two rotating face plates (Mobot wheels and other add-ons are attachable as snap-ons to the face plates).

There are four additional mounting surfaces per module for a total of six. Each module weighs only 18 oz. Joint speed is 120 degrees per second, with a torque in each joint of 100 oz-in.



Close-up of a created and programmed robot pieced together from the Mobot robotic modules from a student.



A student from Hiram Johnson High School is testing code for the minesweeper Mobot configuration.



Replacing the batteries in a minesweeper configuration.

The platform supports Windows XP, Vista, and Windows 7, and also the Mac OS X, a Graphical User Interface (GUI) robot controller, and a C/C++ interpreter channel for processing and motion control.

"The Mobots are useful in teaching pre-algebra, algebra I, geometry, physics, physical science, computer science, and really anything where abstract concepts can be realized in the physical world to create a greater understanding for students," according to UC Davis. Each unit is individually useful since there is no minimum assembly/setup that needs to occur to get started in the classroom.

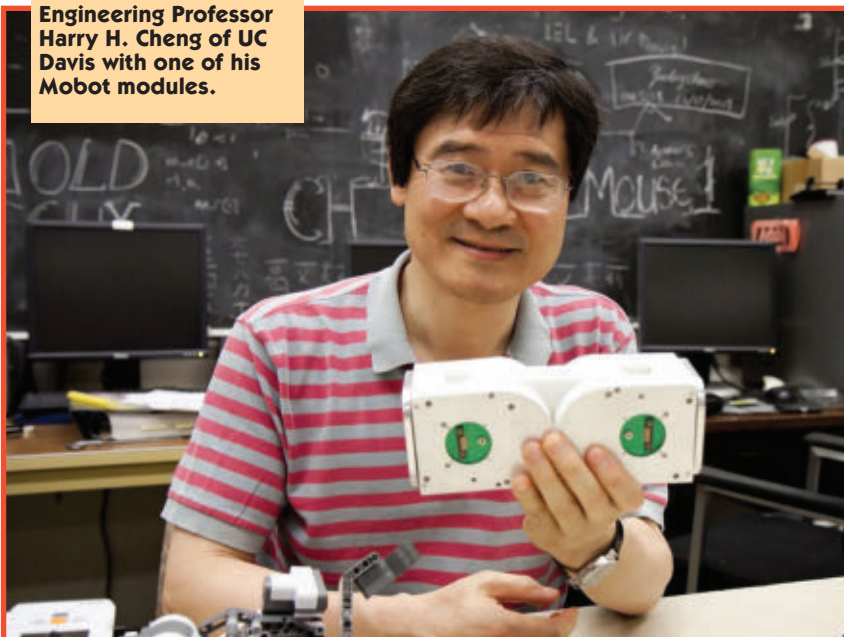
Engineering the Mobot's Wheels — a Lesson in Design vs. Cost

The engineers at Borabo Robotics decided the Mobots needed their own special wheel accessory to make the robots mobile. The eventual design included rounded edges, cut-outs, and extrusions to make sure the wheels had good tread and traction, and remained in contact with surfaces in a way that enabled the robots to continue to be locomotive — even when the module's joints were bent at an angle.

One approach the engineers considered was a two-sided shell design with dead space inside which could be plastic injection molded with snap connection joints to connect it to the Mobot's rotating interfaces. However, the Borabo design engineers found the injection molding approach challenging since the molds required to create the snap-on features were pricey. Even a less expensive bump-off process that adds the overhang features during removal from the mold could not be applied to the entire wheel, so another approach had to be found.

A single-sided design approach was then considered. This led to several iterations including a treaded wheel with a central rib, enabling even rolling. The design could be easily molded in an inexpensive fashion with no overhang or special procedures. Still, the engineers had to reduce the width of the wheel in an attempt to come in under budget. This helped but was not enough.

Engineering Professor Harry H. Cheng of UC Davis with one of his Mobot modules.



A student demonstrates a Mobot robot that has a mobile arm that can move objects.

So, they put the wheel on the back burner, knowing that later it could become more affordable, and that it might also be feasible to produce some limited number of plastic printed units. However, this also presented challenges as the design had to change to suit plastic printing.

The design was adjusted further to reduce the wheel wall thickness and rid some surface drafts for material cost savings. They also had to move the rolling ring to the inside of the wheel to eliminate the need for support materials for the printing process. However, the engineers ultimately liked the original injection molded wheel best, and had a prototype made up of it.

Recognition and Funding by the National Science Foundation

In April 2012, Barobo Robotics received a second round of funding from the National Science Foundation worth approx. \$500,000 over two years. The west Sacramento company had the potential to earn an additional \$500,000 in funding over the next two years if the company could effect some sales and land venture capital funding. Cheng and Ryland started the robot company in 2011 and initially received a \$150,000 grant from the NSF.

This milestone is critical to turning Mobots into a commercial product for the education sector. Professor Cheng is eager to see students learn from the Mobots as early as the third grade level.

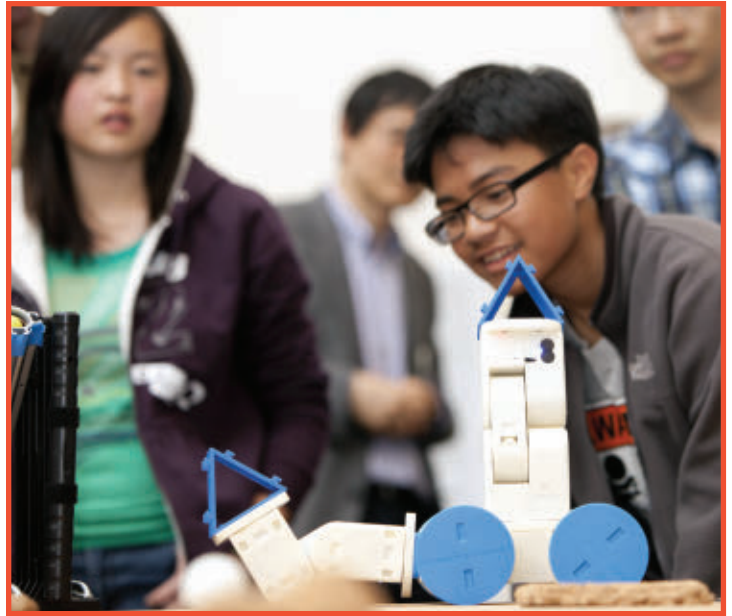
The Mobot platform is recognized for its ability to turn wheels at each end of a single module, crawl on its hinges, and raise one end of its body and move around.

Cheng and Barobo Robotics are already working with middle and high schools in their regional area. Students are urged to design and build new parts for their robots using 3D printing procedures.

Professor Cheng also started the UC Davis K-14 Outreach Center for Computing and STEM Education (C-STEM). The C-STEM center held a RoboPlay Competition in May 2012 to encourage local students to demonstrate their new Mobot projects.

Conclusion

Younger and younger students in elementary schools are learning robotics and complex skills such as high math



and robot programming. With the goal of extending robotic creation and instilling programmable intelligence to kids as early as the third grade level, Mobots hope to be an integral part of this building process. **SV**

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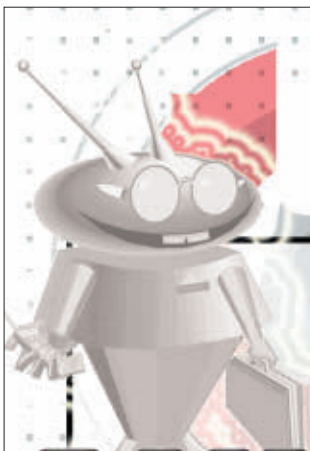
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Resources

Barobo Robotics
www.barobo.com

UC Davis STEM Center
<http://c-stem.ucdavis.edu>



Our resident expert on all things robotic is merely an email away.
roboto@servomagazine.com

Tap into the sum of *all human knowledge* and get your questions answered here! From software algorithms to material selection, Mr. Roboto strives to meet you where you are — and what more would you expect from a complex service droid?

ASK MR. ROBOTO

by
Dennis Clark

As I write this article, the madness of First LEGO League 2012-2013 is upon us, and my team is scrambling with last minute polish to programs and project presentations. I'm keeping a bunch of fifth and sixth graders very busy. By the time you read this, things will be quieter here in the lab, where I only have about six projects that I want to finish and another six I'm thinking about starting. (Who says ADHD is a bad thing?) Anyway, on to my question of the month.



Figure 1

Q. I want to use a Roomba a friend gave me to make a robot. What processor does it use? How do I program it? What sensors does it have? Can I use them for my own programs?
 Any help you can give will be WAY appreciated!
 — **Moby, in Colorado**

A. Whoa! Slow down there! You've asked enough questions for a few columns! Let's look at what we know about the Roomba and see what I can answer.

For those of you that live off-grid in a Dennis Weaver tire house, **Figure 1** is an example of the Roomba. In this

case, it is the one that I *didn't* hack because it keeps my lab floor clean. The other 99% of you probably have a Roomba or know someone who does.

The red Roomba I hacked for this article was sitting in the back of my closet because its battery charger had died. I put together a couple of wires and got its battery charged on my handy Hitec Multicharger X4.

For those of you wondering, the Roomba battery is a 14.4V (12 cell) NiMh battery. I *think* it is about 4,000 mAh capacity, but the screws on it were weird so I didn't open the case to see. That is just what I managed to jam into the pack before it peaked. I may upgrade to a LiPo battery someday to get more capacity and a better charge time.

Location	Sensor	Purpose
A	Motor wheel drop sensor	Robot stops when a wheel drops off an edge.
B	IR "cliff" sensors	Detects stairs when driving forward.
C	Bumper sensors	Knows left-right-center collision detection.
D	Wall follower IR sensor	Helps robot to follow a wall on the right.
E	IR beacon dome	Used to locate a virtual wall and charge dock.
F	Tail wheel drop sensor	I <i>think</i> the robot will stop and go forward.

Table 1.

The Roomba appears to use a Freescale MC9S12DG256 microcontroller. However, iRobot has done such a wonderful job on the sensor integration and motor controllers of the Roomba that I would be loathe to mess with it.

Leave the code in the Roomba robot as it is and look at how we can interface it to what is already there (rather than throwing out the baby with the bath water). My quick answer is: Don't program it. Connect to it using the iRobot serial command interface (more on that later).

The Roomba has *lots* of sensors in it; most of them are useful to us, while at least one of them is a real puzzle to me (the dirt sensor). Look at **Figure 2**. I have labeled the sensors shown inside the main body as detailed below:

As far as I can tell, the **(A)** motor drop sensors simply stop the robot to keep it from tumbling down the stairs if a wheel falls off a cliff. These are simple microswitches that are triggered when the spring-loaded wheel drops.

The **(F)** tail wheel-drop sensor is one that I've not maneuvered the robot into using yet, but if I had to guess I'd bet it would make the robot stop going in reverse and go forward.

The **(B)** IR cliff sensors are really good at seeing a drop-off/on either a carpeted or hardwood floor. (I'd love to know how they did that! My IR proximity detectors are typically confounded by carpeting.) The bumper sensors do what you would expect.

There are two IR slotted interrupter sensors **(C)** that the highly flexible front bumper can activate. If you collide on the right, only the right sensor is triggered; the same —

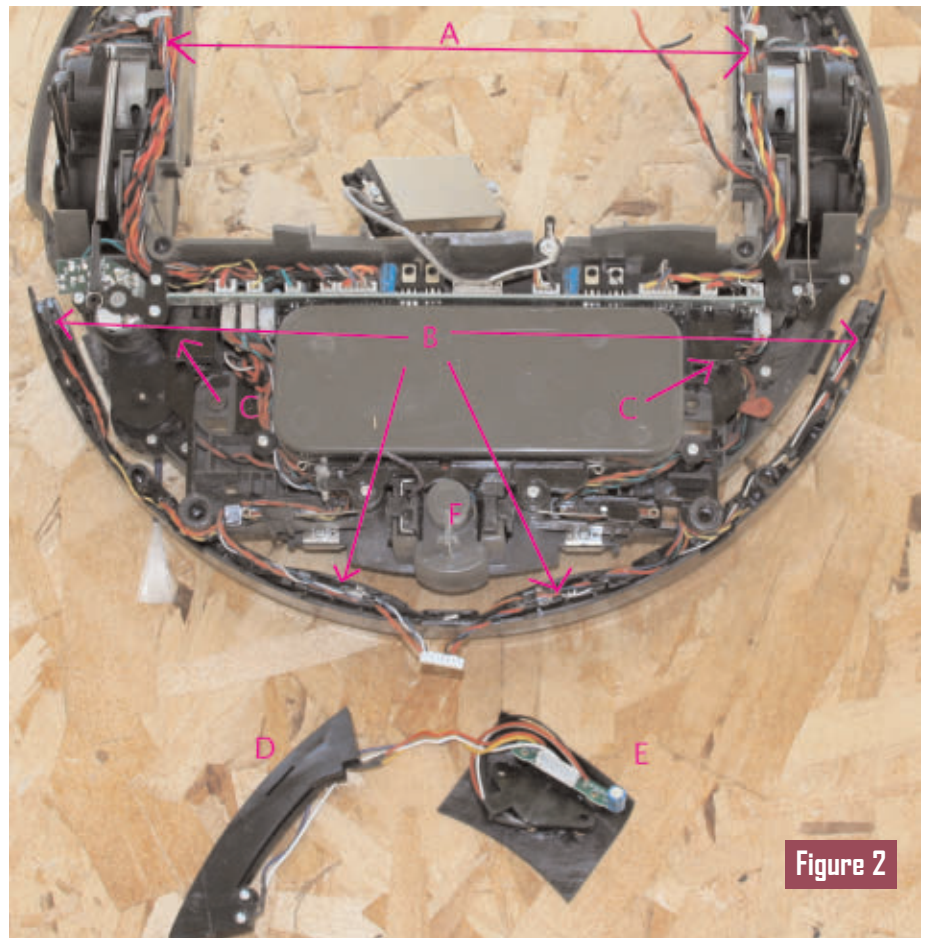


Figure 2

but opposite — is true for the left side. If you hit more or less in the center, then both of the sensors are triggered. The robot changes course accordingly. (If you've ever seen a Roomba in action, you marvel at how well it determines the correct course to take).

The wall follower IR sensor **(D)** is most likely (I've not confirmed this) a fixed distance IR sensor that allows the Roomba to hug the wall when it finds one. It can also nicely navigate an inside or outside corner with this. (It is cool to just watch this little guy in action!)

Finally, there is **(E)** the IR beacon sensor dome. This watches for messages from the charging dock (if your model supports it) or the "virtual wall" beams that tell the Roomba when it has reached the end of its allowed space going forward. It is the efficacy of the programming that supports these sensors that makes me suggest that you are better to send messages to the Roomba using the SCI interface than writing your own OS for it. **Table 1** gives a quick summary of all these sensors.

As a robot hacker, I've never seen a re-purposed robot that is so flexible and able. As anyone can tell you, making a highly maneuverable robot can be a challenge if you want it to work on hard floors or carpeting. The Roomba does this with ease.

The drive wheels are *very* grippy and their spring-loaded suspension makes them very adaptable to terrain

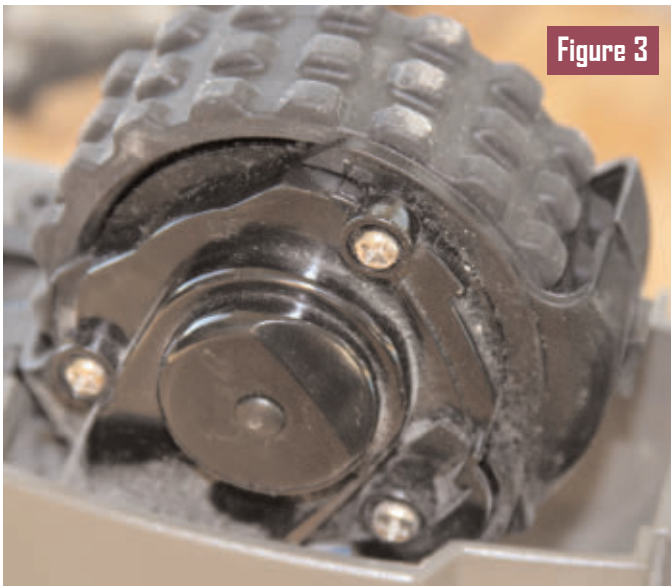


Figure 3

variations (**Figure 3**). The motors are strong — if a bit noisy — and drive the robot at a good indoor clip.

The tail wheel turns well and doesn't mess up the robot when backing up — which is another great engineering feat! The tail wheel on my red Roomba is different than on my blue one, but both work well. One of the first things I noticed when I hacked off all of the vacuum cleaner bits and trimmed my Roomba down to its bare bones is that when it slows down, the body lurches up and both drive wheels "drop." This causes the robot to stop and lurch around.

One way to fix this would be to weaken the springs on the wheel supports (**Figure 4**). I tried this, but was unwilling to allow too much slop. If you look closely at **Figure 5**, you'll see two old six-cell RC car batteries stuck to either side of the "cargo bay." These add about a pound of weight and (with a small stretch of the springs) allow my robot to keep its "feet" on the ground when maneuvering.

Because I wanted to keep the auto pilot modes available to me, I hacked the buttons out of the top plate when I eliminated the unneeded bits (refer again to **Figure 5**). I plan on doing something more elegant when the final project is completed, but this keeps me going on with it.

Now that we have described the physical aspects of the Roomba, it is time to learn how to control it. Fortunately for us, iRobot had hackers in mind when they made the Roomba.

There is a serial port — typically just over the power plug for the charger — which has a female mini DIN connector; see **Figure 6**. I'm not sure where to find the mini DIN connector used on the Roomba, but I know where to get something that is close.

I have a collection of old mice and miscellaneous cables, including PS2 mice and *ancient* Macintosh printer cables. There is a little plastic registration stud in the middle of these six mini DIN male cables that prevents them from working in the Roomba connector. No

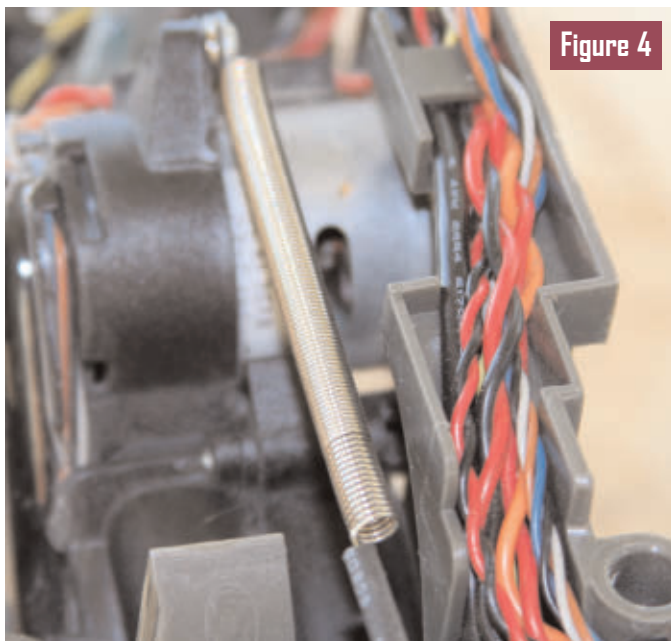


Figure 4

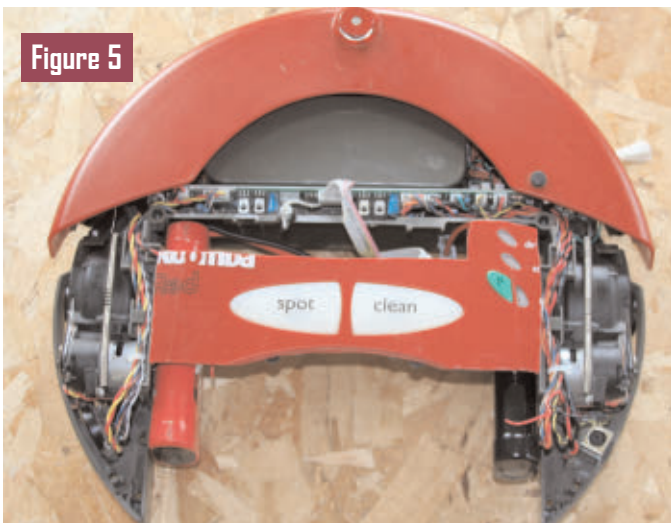


Figure 5

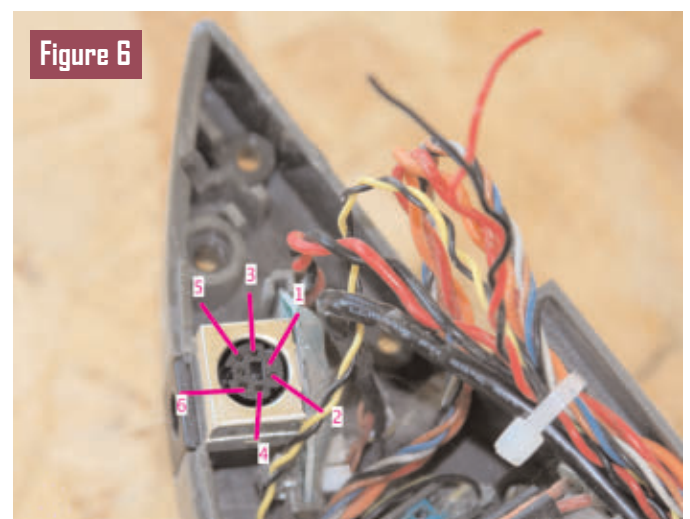


Figure 6

problem! Modify the connector!

Using a small-tip pair of long-nose pliers, carefully grab the plastic stud and twist it until it snaps off. The registration slots on the metal case of the connector will properly align with the Roomba mini DIN connector, and everything will work fine. See **Figure 7** for a typical mini DIN six-cable connector which clearly shows the center plastic registration stud removed. (In **Figure 6**, I labeled all of the pins but one — pin 6.

Table 2 gives the description for all of the pins, whether we are using them or not.

Unless you have a mini DIN connector with seven pins, you won't be able to use pin 6 which will limit the current that you can pull from the battery for this connection. For our use with a low-power microcontroller, this won't be an issue. If you are going to try to power a PC104 board (high current requirements), you might want to use a separate battery and use pin 7 to make your grounds common.

The iRobot SCI interface protocol is not in ASCII, so you can't use a terminal emulator to talk to it. Because of this, iRobot thoughtfully did *not* require you to use an RS-232 level translator to use the port; you can use the serial output directly from your microcontroller to talk to the Roomba.

Many people call the asynchronous output from a UART on a micro "RS-232." It isn't. RS-232 refers to the electrical specification that describes the signal levels that appear on the *other side* of the RS-232 level translators that you attach to your microcontroller. This causes some confusion, so be the first on your block to correctly name this.

The iRobot SCI specification states that this is a 0-5V logic level, so if you are using a micro whose native output is 3.3V, you will have to do a level translator which isn't hard. (See my October 2012 article about using a wireless PS2 controller which gives a good circuit for doing this voltage level translation.)

iRobot is pretty coy about their manuals for hacking the Roomba, so you aren't going to just navigate their site to find them — at least I couldn't find them by wandering the site. However, you can find them using their search window. Here are a few of the fun things that you can find; some of them are for the iRobot Create, which is their hacker hobbyist-only version of the Roomba. The one that we're interested in is the iRobot Roomba Serial Command Interface Specification. Here are the manuals that I found on their site:

- *iRobot Roomba Serial Command Interface (SCI) Specification*
- *iRobot Create OPEN INTERFACE*
- *iRobot Create OWNERS GUIDE*
- *iRobot Command Module OWNERS MANUAL*

Go hunting at www.irobot.com.

Next month, we're going to dig into the SCI manual

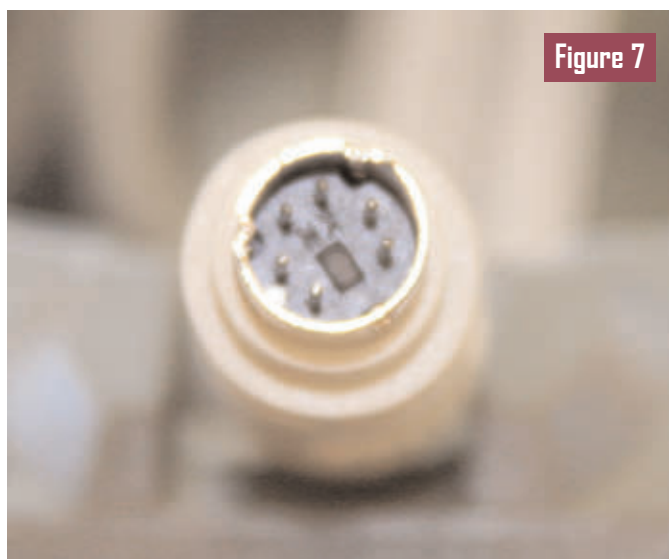


Figure 7

and start controlling the Roomba from an Arduino. Yeah, I'm going to use the Arduino for a couple of reasons: It is easy to use and I'm essentially lazy when it comes to re-inventing a wheel. If someone has already written an SCI command translator interface for the Arduino, I'm gonna use it! The Arduino is a 5V microcontroller system, so we can interface its UART directly to the SCI connector and run.

I've looked through this manual a little and noticed that you can set the Roomba to a variety of modes. You can not only control its motors, but also get detailing information about the state of its many sensors. It doesn't look too hard to use, either.

So, until next month, think about the possibilities or jump the gun and write to me with your findings, suggestions, or requests.

I've come to the end of another Mr. Roboto column and it seems there is still so much more to do! That is the wonderful thing about a hobby — especially this one. There is *always* more to do! So, send me your emails to roboto@servomagazine.com and I'll do my best to answer them. **SV**

Pin	Name	Description
1	Vpwr	Roomba battery + (unregulated)
2	Vpwr	Roomba battery + (unregulated)
3	Rxd	0-5V logic level asynchronous serial input to Roomba
4	Txd	0-5V logic level asynchronous serial output from Roomba
5	DD	Device detect input (active low) used to wake Roomba up
6	GND	Roomba battery – (Not connected on a cable)
7	GND	Roomba battery – (Unregulated)

Table 2.

EVENTS

Calendar

ROBOTS.NET

Send updates, new listings, corrections, complaints, and suggestions to: steve@ncc.com or FAX 972-404-0269

Know of any robot competitions I've missed? Is your local school or robot group planning a contest? Send an email to steve@ncc.com and tell me about it. Be sure to include the date and location of your contest. If you have a website with contest info, send along the URL as well, so we can tell everyone else about it.

For last-minute updates and changes, you can always find the most recent version of the Robot Competition FAQ at Robots.net:

<http://robots.net/rcfaq.html>.

— R. Steven Rainwater

JANUARY

3-5

Techfest

Indian Institute of Technology, Bombay, India
Events include an International Robotics Challenge, TechOlympics, Robotron, Dimensions, Xtreme Machines, and Code Czar.

www.techfest.org

11-12

FIRST LEGO League of Central Europe

Obrigheim, Germany

This is the big FIRST LEGO League championship event for the area.

www.hands-on-technology.de/en/firstlegoleague

22-23

Singapore Robotic Games

Science Centre, Republic of Singapore

The games include lots of events: picomouse, Sumo, robot soccer, wall climbing, pole balancing, underwater robots, legged robots, robot colony, humanoid competition, and the intelligent robot competition.

<http://guppy.mpe.nus.edu.sg/srg>

24-27

ION Autonomous Snowplow Competition

St. Paul, MN

Just what it sounds like — autonomous snowplow robots must remove snow along a designated path.

www.autosnowplow.com

FEBRUARY

1-3

Quark Roboficial

Goa, India

Student competition for autonomous robots with a variety of events.

www.bits-quark.org

1-4

Robotix

West Bengal, India

Events at the competition include Abyss, Overhaul, A.C.R.O.S.S., Lumos, The Seeker, and Marauder's Map.

www.robotix.in



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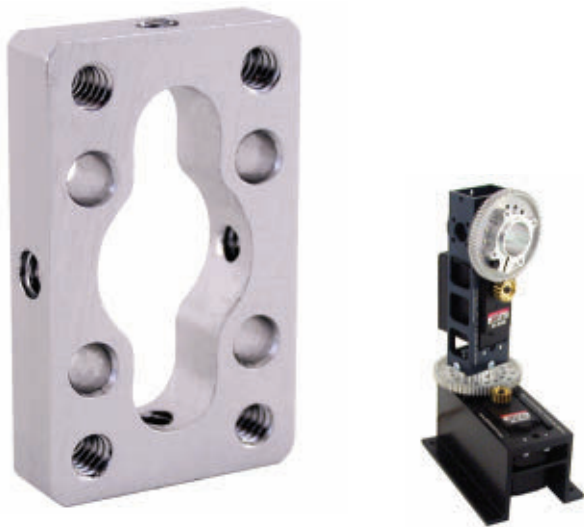
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NEW PRODUCTS



Aluminum End Caps

New aluminum end caps from ServoCity fit into the end of their 1" x 1.5" tube gearboxes, and allow users to attach any of their .770" pattern components to the gearbox. The end cap has a 1/2" center bore to allow tubing or shafting to extend inside of the gearbox for added support. When using hollow tubing, it allows wires to be routed through the interior of the gearbox and down the hollow tube for a clean look.

The end cap is constructed of 6061 T6 aluminum for strength. Using the end cap with a ServoCity tube gearbox and attaching it to a bottom mount gearbox (pictured) is used as a setup for antenna tracking systems.

Servo Power Tube Gearboxes

ServoCity is also introducing a new patented SPG785A1-5 servo power tube gearbox. A stock HS-785HB servo can rotate 3.5 turns (1.75 turns left or right from center) or

1,260° total. When the HS-785HB servo is installed into this tube gearbox, the total amount of rotation is decreased but power and accuracy is increased. Position feedback remains since the internal potentiometer is not removed.

Choose the necessary gear ratio along with the amount of rotation an application requires. The lower the gear ratio, the more precision and power is available, but with less rotation. The SPG785A1-5 can handle tremendous side loads with the dual ABEC-5 precision ball bearing supported 1" aluminum hollow shaft. The shaft is hollow to allow wires from cameras, sensors, or other devices to not tangle during multi-turn rotations. The frame of the SPG785A1-5 is machined from 6061-T6 aluminum (anodized) and offers ServoCity's 0.770" hub pattern in line with the output shaft.

For further information, please contact:

ServoCity

Website: www.servocity.com

New GestIC Technology Enables Mobile-Friendly 3D Gesture Interfaces

Microchip Technology, Inc., is now offering its patented GestIC® technology which enables the next dimension in intuitive, gesture-based, non-contact user interfaces for a broad range of end products. The configurable MGC3130 is an electrical field (E-field) based 3D gesture controller offering low-power, precise, fast, and robust hand position tracking with free-space gesture recognition.

With power consumption as low as 150 microwatts in its active sensing state, the MGC3130 enables always-on 3D gesture recognition — even for battery-powered products where power budgets are extremely tight. In fact, the MGC3130's low-power design and variety of configurable power modes provide the lowest power consumption of any 3D sensing technology — up to 90% lower than camera-based gesture systems.

GestIC technology achieves its gesture recognition rates through its on-chip library called the Colibri Suite of intuitive and natural human gestures. The Colibri Suite combines a stochastic Hidden Markov model and X/Y/Z hand-position vectors to provide designers with a reliable set of recognized 3D hand and finger gestures that can be easily employed in their products.

Examples include wake-up on approach, position tracking, flick gestures, circle gestures, and symbol gestures to perform functions such as on/off, open application,



point, click, zoom, scroll, free-space mouseover, and many others. Designers can use this library to get to market quickly and reduce development risks by simply matching their system commands to Microchip's extensive set of predetermined and proven gestures.

Additionally, the chip provides developers the flexibility to utilize pre-filtered electrode signals for additional functionality in their applications.

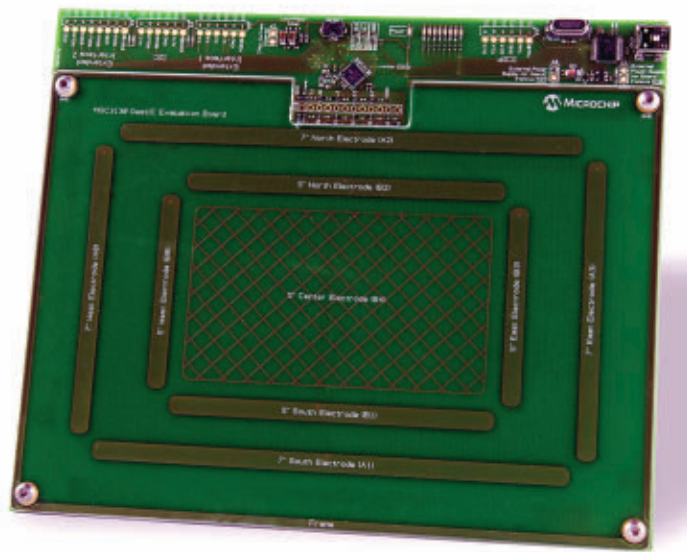
GestIC technology utilizes thin sensing electrodes made of any conductive material — such as printed circuit board (PCB) traces or a touch sensor's Indium Tin Oxide (ITO) coating — to enable invisible integration behind the device's housing. This allows for visually appealing industrial designs at very low total system costs. Additionally, the technology provides 100% surface coverage, eliminating "angle of view" blind spots found in other technologies.

With a detection range of up to 15 cm, the MGC3130 is the ideal technology for products designed to be used in close proximity for direct user-to-device interaction. With its range of configurable smart features, the MGC3130 uniquely enables the next breakthrough in human-machine-interface design across various industries.

Example applications include keyboards that take advantage of the advanced interface capabilities in the new Windows® 8 operating system using hovering motions and free-space gesture controls instead of reaching over to touch a screen.

The MGC3130 provides a sophisticated, precise, and robust 3D gesture-interface and hand-position tracking solution with features such as:

- 150 DPI, mouse-like resolution, and a 200 Hz sampling rate to sense even the fastest hand and finger motions.
- Super-low-noise analog front end for high accuracy interpretation of electrode sensor inputs.
- Configurable auto wake-up on approach at 150



microwatts current consumption, enabling always-on gesture sensing in power-constrained mobile applications.

- Automated self-calibration for continued high accuracy over a product's lifetime.
- 32-bit digital signal processing, for real time processing of X/Y/Z positional data and the Colibri Suite gesture library.
- Integrated Flash memory for easy upgrading of deployed products in the field.
- 70-130 kHz E-field with frequency hopping to eliminate RF interference, and resistant to ambient light and sound interference.

For further information, please contact:

**Microchip
Technology, Inc.**

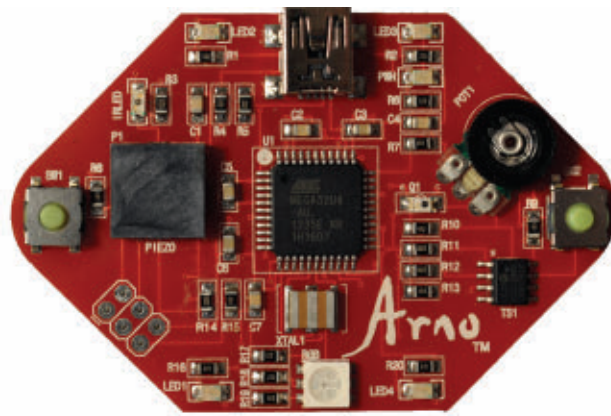
Website: www.microchip.com

Arno Kit for Arduinos

The Arno Kit from Olympia Circuits is an innovative new approach to learning and teaching about Arduino. The Arno provides beginners with interesting circuits built right into the board, so they can focus on learning the basics of electronics and the Arduino language without needing to assemble and troubleshoot circuits.

The kit consists of the Arno circuit board and a new book that gives step-by-step instructions for more than 40 projects, without the need for external components and wiring. The Arno board is based on an ATmega 32U4 processor from Atmel. The included book *Learning Arduino with the Arno* gives all the information needed to move into advanced projects. It is a thorough text to teach a wide range of programming concepts.

The projects range from common beginner programs

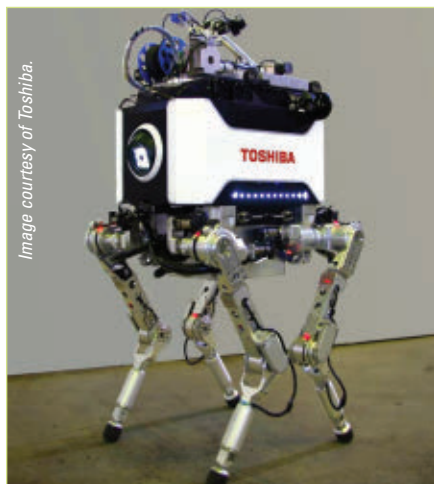


like "blink," to more complex concepts using multiple inputs and outputs. For further information, please contact:

**Olympia
Circuits**

Website: www.olympiacircuits.com

bots IN BRIEF



WALKING THE QUAD

Robots played a key role in assessing damage and radiation levels at the Fukushima nuclear power plant which was crippled by the massive earthquake and tsunami that struck Japan more than a year ago. All the robots that were used relied on tracks to navigate inside the reactors, in addition to aerial vehicles that were implemented to observe the site from above. None of the robots had legs.

Toshiba is about to change that. The company announced recently that it plans to send a quadruped robot to the disaster site.

The remote-controlled, radiation-resistant quadruped has multiple cameras and carries a dosimeter. Its legs are powered by electric motors (unlike BigDog and HyQ — two quadrupeds that use hydraulics).

One news outlet said the robot resembled a "headless dog." Another described the robot as "an ice cooler on wobbly metal legs." Either way, it's a cool-looking machine. Unfortunately, reports of the robot's first demonstration were less impressive. Apparently, the robot slowly climbed a flight of just eight steps (taking about a minute to go up each step) and at one point, the robot stalled so Toshiba engineers had to pick it up and reboot it.

The company said the robot also has "a folding arm that can release a companion smaller robot," but details about that capability are hard to find.

The Fukushima site and its surroundings are still highly contaminated, so it makes sense to send

in more robots, but does it make sense to use a legged robot? From a research point of view, testing a new platform in a real environment could provide valuable insight.

Some roboticists have long argued that legged machines could perform better than wheeled or tracked ones on difficult terrain. On the other hand, it's hard to see how this newer prototype could outperform an iRobot PackBot or Warrior, with years of real world operation. Or, for that matter, the Japanese ground robot Quince which has a capable multi-track system.

Let's not underestimate the Toshiba robo-dog just yet.

Here are some specs from Toshiba:

Weight: 65 kg

Size: 624 mm (L) x 587 mm (W) x 1,066 mm (H)

Power Source: Battery

Battery Time: Two hours
(continuous use)

Weight Capacity: 20 kg

Walking Speed: 1 km/h

Operation: Wireless remote control



PATTY CAKES

Momentum Machines is working on a robotic system — nicknamed Patty — that can cook burgers and toast buns, then slide them down to a compartment where veggies get sliced and placed on the burgers. It then adds condiments and bags them. Apparently, the entire operation takes less than 30 seconds, thereby leaving the human burger worker to join the ranks of the unemployed. The five foot tall prototype is still a work in progress, so it may be a while before a Pattyburger is actual competition.

bots IN BRIEF

JUMP TO IT

Jumping can be a great way to get around. It's far more efficient than flying and much more versatile than driving or walking or crawling. Jumping robots need a big burst of power to get off the ground, but after 20,000 jumps' worth of analysis, researchers at Georgia Tech have found a secret that makes robotic hops ten times more efficient: It's a stutter (a little jump) right before the first big jump.

That's it. That's the secret. It's simple, but it makes a huge difference. Daniel Goldman, one of the authors on a paper published in *Physical Review Letters*, explains:

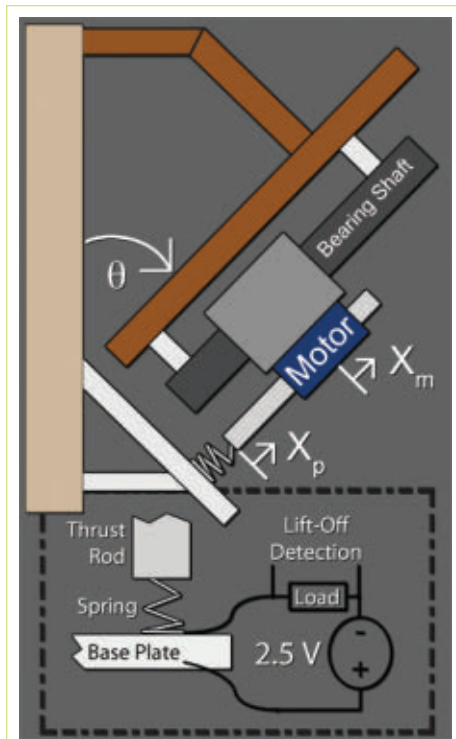
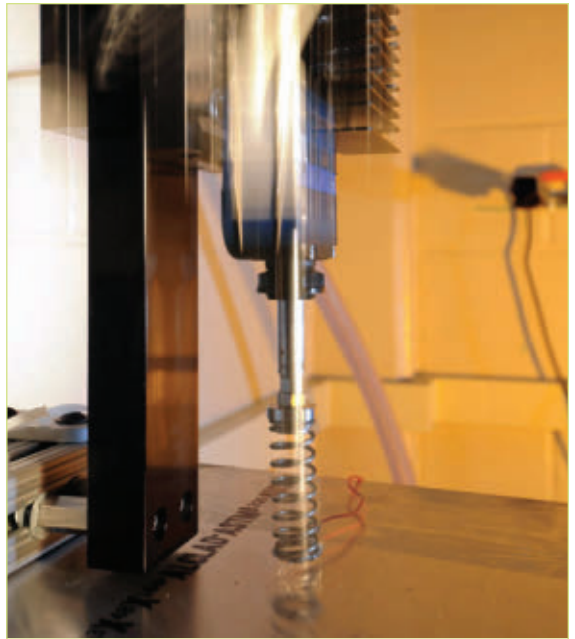
"If we time things right, the robot can jump with a tenth of the power required to jump to the same height under other conditions. In the stutter jumps, we can move the mass at a lower frequency to get off the ground. We achieve the same takeoff velocity as a conventional jump, but it is developed over a longer period of time with much less power."

How much less power you ask? Up to ten times less. The jump takes longer to make because of the initial hop that's required, but that seems like a small price to pay to keep your robot bouncing ten times longer on the same amount of power.

This trick works with "pogo stick" jumping robots which are bots that use springs to store energy. Georgia Tech built themselves the most simple jumping robot possible to run their experiments; it consists of a leg, a spring, and an actuating mass. They expected to find that the optimal jumping strategy would be related to the resonant frequency of the system, but after ten thousand tests or so, it turned out that frequencies above and below the resonance led to optimal jumping. That's where the stutter jump comes from.

You can check out the robot at <http://crablab.gatech.edu/pages/jumpingrobot/Demo.html> for yourself. It's a nifty little interactive part of the website that lets you virtually mess around with the jumping robot used in these experiments.

The researchers plan to keep on experimenting with this robot on a variety of surfaces, including sand and disaster-type environments.



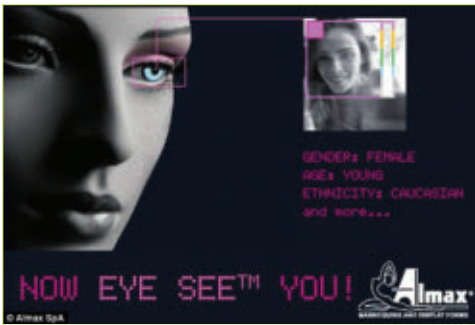
A linear motor was attached to an air bearing for near frictionless 1D motion. Due to the weight of the air carriage, the apparatus was slanted to an angle of $\theta = 75^\circ$ to reduce the gravity load on the motor to 0.276 g.

Total mass load on the spring: $m = 1.178 \text{ kg}$

Spring stiffness: $k = 5.8 \text{ kN/m}$

Damping ratio: $\zeta \sim 0.01$ (from video tracking data of free oscillations)

Lift-off was detected at a rate of 1,000 Hz by reading the voltage of a circuit that would open and close at the interface of the bottom of the spring and the metal base.



I GOT MY EYES ON YOU

Beware! That mannequin may be watching your every move!

Almax's EyeSee technology has facial recognition and can log age, gender, and race of unaware shoppers. This can be useful in determining shopping habits of retail customers and keeping an eye on would-be shoplifters.

The Italian-based company also plans to add screens nearby to alert customers to specific items they can purchase which are relevant to their profile.

These mannequins from Almax and Kee Square – a spin-off of Politecnico di Milano – can not only display clothing collections, but can encourage consumers to enter the store. They make it possible to "observe" who is attracted to window displays and the time spent looking at items.

Here's how it works:

A special camera connected to special software is installed inside the mannequin's head.

This software analyzes the facial features of people passing by, and provides statistical and contextual information useful to the development of targeted marketing strategies.

The embedded software can also provide other data such as the number of people passing in front of a window at certain times of the day. So, buyers beware!



ROVER ALL OVER

The Rover Spy Tank from Brookstone is a spy camera on wheels that both adults and kids will love. The rover creates its own Wi-Fi connection and can be controlled via iPhone, iPad, or iPod touch. An adjustable front-mounted camera streams video and takes photos, while a built-in microphone sends back audio. The device has night vision capability and runs on six AA batteries (included). Also included is access to a free app to control the tank.

The dual function camera sends a live video feed from the vehicle as it moves along its path on its tank-tread wheels, and takes still pictures that can be shared with friends. It can travel up to 200 feet away from the user which makes it perfect for remote surveillance on big sisters.

With its wireless range of up to 200 feet, plus the infrared night vision, it's ideal for those late night missions.



BODY DOUBLE

A figure model based on AIST's female android is being manufactured by WAVE Corporation — a model company which previously sold kits based on Honda's P2 and P3 humanoid robots. The 1/12 scale model kit (14 cm tall) requires assembly, but the parts are already painted and feature easy snap-fit construction. It is also fully posable, and comes with three heads for different expressions ("normal," "surprised," and "angry"). The kit won't be shipped until February, but it can be pre-ordered online at stores like Ami Ami and Hobby Link Japan for around \$28 USD (not including shipping).

ROBOT IN A DEEP HOLE

William 'Red' Whittaker hopes that by 2015, his robot — or something like it — will be rappelling down a very deep hole on the Moon.

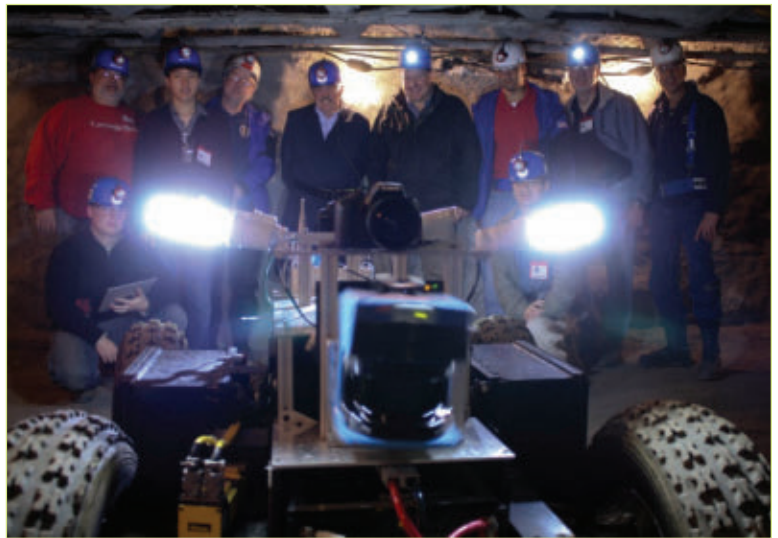
This hole was discovered a little over three years ago when Japanese researchers published images from the satellite SELENE1. However, spacecraft orbiting the Moon have been unable to see into its shadowy recesses.

"This is authentic exploration. This is the real deal," says Whittaker — a roboticist at Carnegie Mellon University in Pittsburgh, PA — whose robots have descended into an Alaskan volcano, and also helped to clean up the Three Mile Island nuclear power plant. "This is really going where none have gone before."

Over the next two years, the NIAC (NASA Innovative Advanced Concepts) program will spend about \$500,000 USD developing Whittaker's creations. The prototype he tested at a coal mine could be lowered into the revealed Moon pit to check the walls for openings. A more ambitious approach would be to have a robot that jumps down the hole or lowers itself using a cable. The first prototype of such a machine — a four-wheeled cave crawler — can drive itself around underground and is already practicing in the mine's tunnels. Onboard lasers sweep the floors, walls, and ceilings to map out the tunnels.

Ever since the hole was discovered, researchers have been keen to work out its origin. Estimated to be about 65 meters wide and at least 80 meters deep, it seems too big to be just a crater. Plus, its location in the once-volcanic Marius Hills region suggests that the opening is a 'skylight' — an entrance to an intact horizontal tunnel beneath the surface, carved long ago by flowing lava.

Lava tubes have long been considered good locations for building lunar bases. "Their rocky ceilings can protect humans

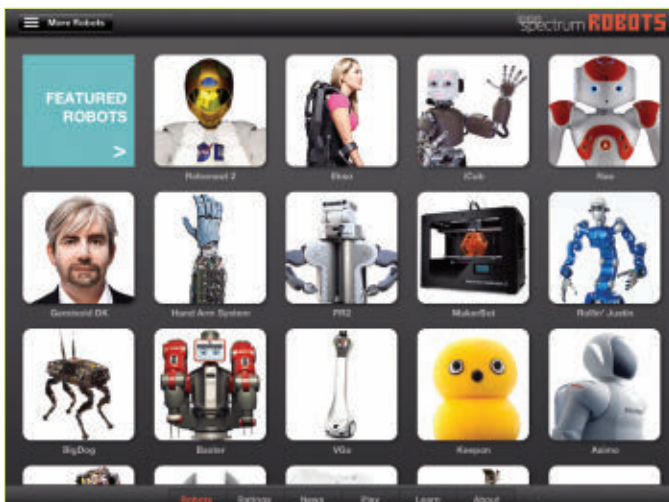


William Whittaker's cave-crawling robot could one day explore lunar caverns.

from micrometeorite impacts and cosmic rays," says Carolyn van der Bogert, a geologist at the University of Münster in Germany.

Protected Moon caves may also house records of the history of the Moon and solar system. Rocks that have been shielded from damage could look just like the surface did when it first cooled, or have textures that have been molded by hidden processes going on inside the Moon, explains Penelope Boston, a cave scientist and astrobiologist at New Mexico Tech in Socorro. Solar wind particles implanted billions of years ago could also provide clues about the early evolution of the Sun, according to van der Bogert.

"We don't really know what's down there," says Boston. "We might be punching down through to a deeper layer that we have not seen from the small amount of lunar material collected at the surface."



APP FOR AVID ROBOT FANS

Robots are one of those things that capture the imagination of people of all ages, backgrounds, and nationalities. "Robots for iPad" is a new app featuring the world's coolest robots, brought to you by IEEE Spectrum. If you want to know how robotics is going to change the world, this tool is for you.

The app (which is now available in Apple's app store) includes 126 robots from 19 countries. You can spin robots 360 degrees, review detailed technical specs, see photos and videos, and much more. For all the features and screenshots, check out <http://robotsforipad.com>.

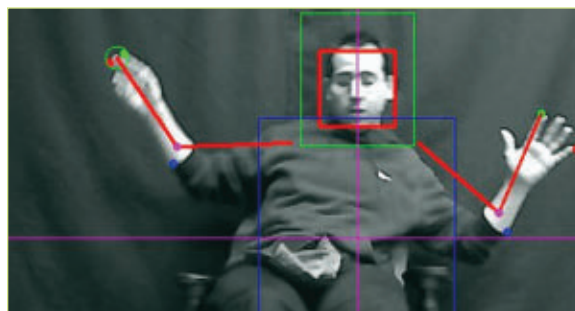
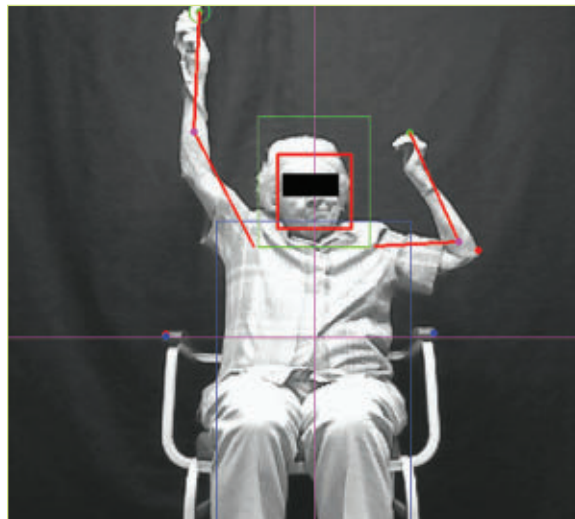
BANDIT SAYS "STICK 'EM UP"

The USC Robotics Research Lab recently posted a journal paper online, titled *Using Socially Assistive Human-Robot Interaction to Motivate Physical Exercise for Older Adults*. Were not sure what visions that title may conjure up, but here's what authors Juan Fasola and Maja j. Mataric' are talking about:

"This paper focuses on the design methodology, implementation details, and user study evaluations of an SAR system that aims to motivate and engage elderly users in physical exercise, as well as social interaction to help address the physical and cognitive healthcare needs of the growing elderly population. SAR systems equipped with such motivational, social, and therapeutic capabilities have the potential to facilitate elderly individuals to live independently in their own homes, to enhance their quality of life, and to improve their overall health."

The robot — named Bandit — is a biomimetic anthropomorphic robot which (in this case) means a vaguely humanoid torso mounted on a wheeled platform. The robot attempts to engage the elderly person in a variety of games — some of which involve making arm gestures and asking the human to imitate them. The robot observes and offers advice as they attempt to repeat the exercise.

Studies of interactions with elderly volunteers seem to support the idea that the robot can succeed at motivating exercise in a way humans find enjoyable. You can learn more about the project on the UCS Interaction Lab Robot Exercise System webpage.



ON YOUR MARK II, GET SET...

Robotma.com — an online store dedicated to hobby robot kits — is now offering a new entry-level bipedal robot called ISAMARO Mark II. The first version of the robot cost a hefty 340,000 JPY (approximately \$4,200 USD), but they've managed to cut the cost in half (to 168,000 JPY / \$2,070 USD) by swapping the Kondo-brand servos used in its 19 joints.

They originally went with more powerful servos (19 kg/cm torque), which were replaced by those with a maximum torque of 13 kg/cm. The kit is designed for use in competitions.

ISAMARO specs include:

Height: approx. 350 mm

Weight: approx. 1.9 kg

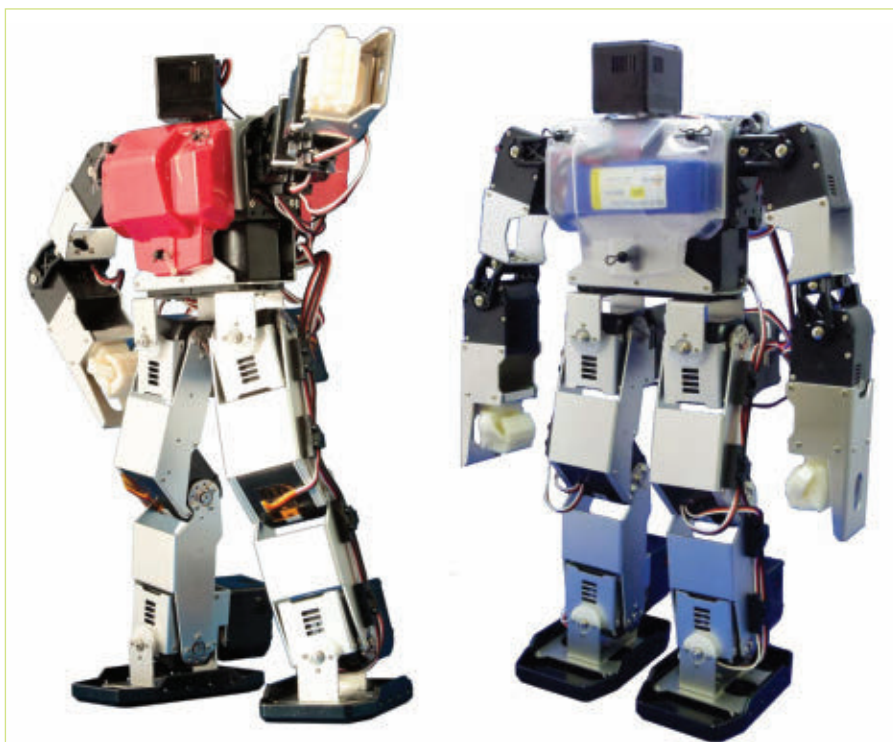
Degrees of freedom: 19

Actuator: KRS-4031HV (19 total)

Optional: Wireless device

Battery: Lithium-polymer

Control board: RCB-4HV



Cool tidbits herein provided by www.botjunkie.com, www.robotsnob.com, www.plasticpals.com, <http://www.robots-dreams.com>, and other places.



microMedic

2013 National Contest

Bryan Bergeron

Nothing spurs technical innovation like competition.

Many of the advances in flight, genomics, and autonomous vehicles are the result of competition for prize money and contracts.

Unfortunately, *most* of the potentially world-changing contests offer multi-million dollar prizes and tend to attract deep-pocketed corporations and universities, leaving folks like you and me to simply watch from the sidelines.

Most, but not all.

One exception is the 2013 microMedic Contest, just announced by the US Army's Telemedicine and Advanced Technology Research Center (www.tatrc.org). The goal of the contest is to showcase how microcontrollers and sensors can be used to create open source medical and healthcare products to improve soldier care in the battlefield, and later as a veteran. Not only is TATRC offering \$25,000 in cash prizes to individuals and teams (18 prizes for those in education; nine for anyone or any team aged 18 or more and not in education), but Parallax will distribute 100 free microMedic Kits, valued at \$400 each. To qualify for a free kit, simply submit a preliminary description of your project idea and promise to participate in the contest. Independent judges will identify which proposals to reward with a free kit.

The microMedic Contest Kit — which isn't required to win the contest — is available in either Propeller or Arduino versions. Each kit includes SPO2, color, pressure, motion, heart rate, temperature, and Hall-effect sensors, LED displays, LED bargraphs, and infrared emitters, as well as a nebulizer, blood pressure cuff, and infrared remote control.

Highlights of the official rules — available at www.parallax.com/micromedic — include six award categories:



- Most Creative Use of the microMedic Contest Kit
- Best Integration of Fabrication
- Best Patient Application
- Best Medical Tool or Device
- Best Medical Training and Simulation Product
- Best Wireless, Telemedicine, or Robotic Application

The timeline is aggressive but doable. You'll have until July 2013 to submit your project. The award ceremony will be held in September at the TATRC Innovation Lab in Fort Detrick, MD. And, with the author's permission, we'll feature the winning projects in upcoming issues of *Nuts & Volts*.

If you're an educator, this would be a perfect project for a STEM (Science, Technology, Engineering, and Math) program for a class, small group, or that special student. Similarly, if you're out of school and either part of a robotics group or a solo microcontroller enthusiast, then this is a good way to focus your experimentation.

If you're not one of the 100 to receive free kits, you're not out of the game. You can purchase kits from Parallax or use your own microcontroller and sensors. The contest is hardware agnostic. The only 'catch' in the contest is that to be eligible for an award, your project must be submitted under the Creative Commons 3.0 Attribution license.

If you're a typical *Nuts & Volts* reader, you probably have little training and exposure to healthcare technology — *and that's the point*. TATRC wants the technology enthusiasts out there to focus on healthcare applications. This may mean brushing up on basic biology and anatomy, or at least pulling a team together that includes someone with a medical background. As such, it's a no-lose proposition. Worst case, you may learn something about human physiology, medicine and medical electronics — *and just maybe* — discover your true passion. **SV**

COMBAT ZONE

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<http://forum.servomagazine.com>

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index.php?/magazine/article/
january2013_CombatZone](http://www.servomagazine.com/index.php?/magazine/article/january2013_CombatZone)

EVENT REPORT:

Seattle Bot Brawl 2012

● by Doug Brown

October in Seattle brought cool temperatures, wind, and rain outside. However, inside the Seattle Center Armory, the competition was heating up at the 2012 Seattle Bot Brawl. This year's event featured one pound Antweight and three pound

Beetleweight battles in an eight foot by eight foot arena with a hazard pit (**Figure 1**).

Previous Bot Brawls have also fielded 12 pound Hobbyweight and 30 pound Sportsman class robots, though this year the arena was only populated by three and

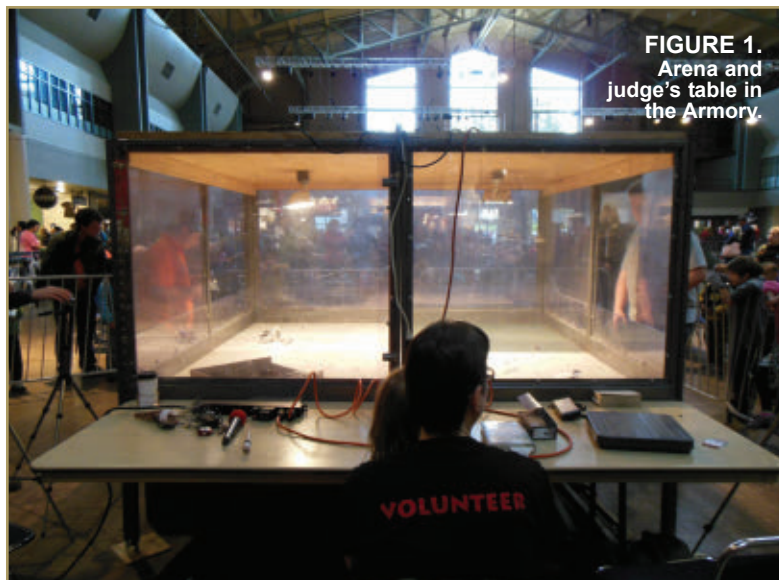


FIGURE 1.
Arena and
judge's table in
the Armory.

one pound Insect class bots. Hosted by Western Allied Robotics (WAR), the event included seven teams with 12 bots from the Pacific Northwest.

Western Allied Robotics has been hosting robotic combat events in the Pacific Northwest for over 10 years; their first event was held outdoors in Seattle's Gasworks Park. (Happy 10th anniversary, WAR!) Some members of WAR have competed in BattleBots and Robot Wars, and several have medaled at RoboGames and COMBOTS.

The Seattle Center Armory (a.k.a., the Center House) is a great venue for a robotic combat event. Newly remodeled, there is plenty of space for the arena, builder pits, and spectator seating. Cafes, shops, and diverse entertainment are all under one roof. Sharing the grounds are the Space Needle, Pacific Science Center, Experience Music Project, and Key Arena.

This year's Bot Brawl included a good mix of newcomers and seasoned veteran builders. Several new bots were introduced at the event. Pugly (**Figure 2**) is a Beetleweight egg beater bot built by Matt Hall of Team Dawg; it's his first robot. Pugly held its own in several rounds of stiff competition. Matt also built an Antweight wedge bot Chewtoy (**Figure 3**).

Chewtoy lived up to its name as saw-blade equipped opponent Velociraptor gnawed on the wedge and armor, but Chewtoy kept on going. Matt made a fine showing for his first event. WAR is always looking for more Antweight robots locally, as it is a much underused class here.

Joshua Beavers of Team Beavers Bots built Whitebox (**Figure 4**), a new Beetleweight wedge reminiscent of Raptor 2.2. At one point in the fight tree, the two bots squared off and it was difficult to tell them apart.

Allosaurus (**Figure 5**) is a new Beetleweight drum spinner built by Doug Brown and Dawson Brown of Team DinoBots. Allosaurus was a scramble build from parts salvaged from retired bot T-Rex 2.0. Despite the short build time, Allosaurus performed well and placed third. Rob Purdy of Gausswave built a new robot called Scram — a Beetleweight four-wheel drive wedge bot.

The wheels were really flying in a fight between veteran builders Kevin Barker and Rob Purdy, with their respective robots Debacle and Wobble Wopper. At first, Debacle had his opponent on the run, tearing into his foam tires and throwing sparks off of his titanium wedge. About halfway through the match though, Debacle's belt broke and became tangled around the shaft of Wobble Wopper's drive. It was a close match, but after Debacle's weapon failure Wobble Wopper took the match by a judge's decision.

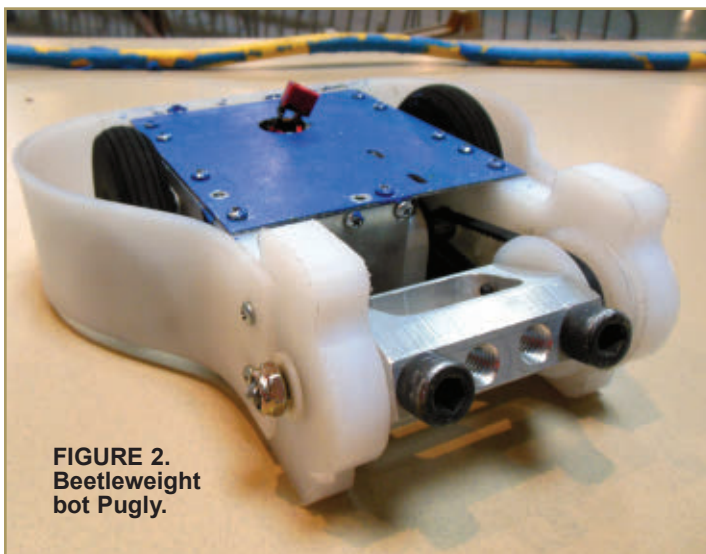


FIGURE 2.
Beetleweight
bot Pugly.

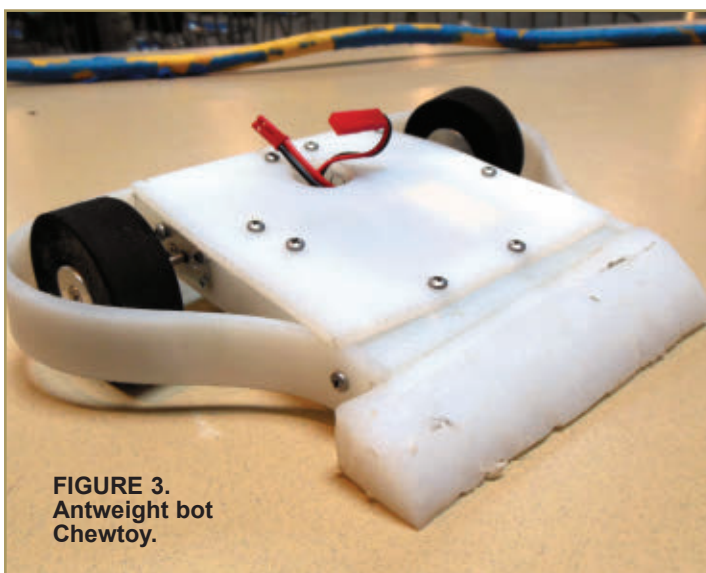


FIGURE 3.
Antweight bot
Chewtoy.

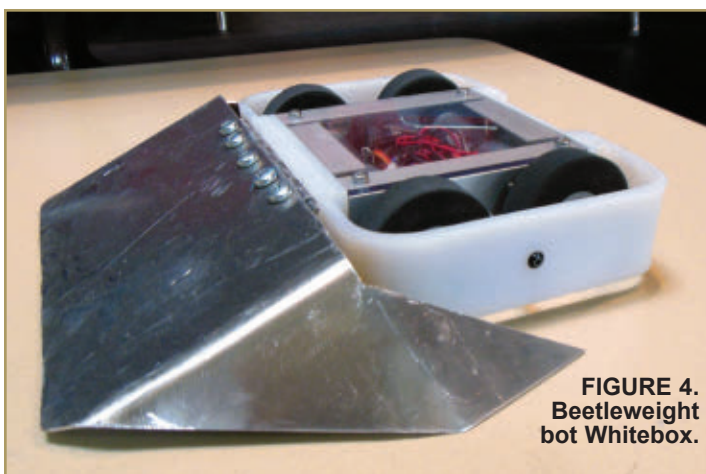


FIGURE 4.
Beetleweight
bot Whitebox.

NQR — built by competitor Dylan of Team Evil
Squirrel — had some intense matches at the Bot Brawl,

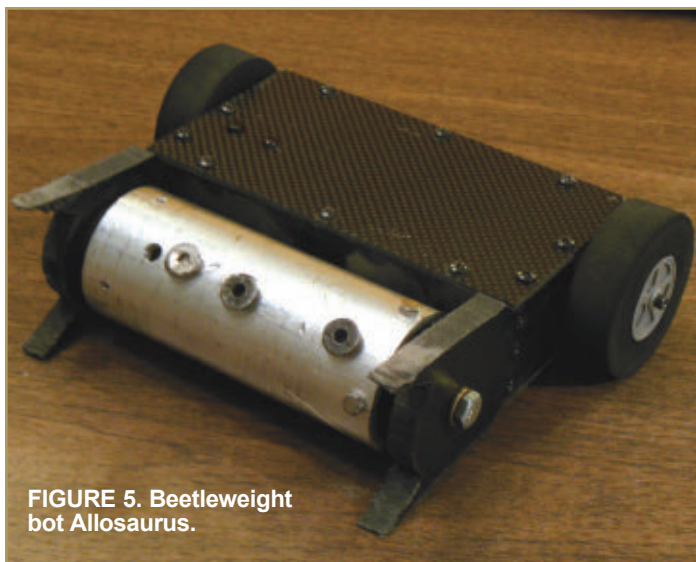


FIGURE 5. Beetleweight bot Allosaurus.

and while he was beaten by the newcomer Whitebox in his second match, he pulled out a win against Debacle — arguably one of the most fearsome robots in the local competition.

Black Box, built by Joshua Beavers, held its own against some tough competitors including the menacing Debacle, but self-destructed by losing his wheels at the worst time.

Starbot Daisy (**Figure 6**) is a Beetleweight robot that eight year old Samantha has been driving for a few competitions, and it has been revised over time. Samantha is the daughter of Rob Farrow (one of the organizers of the event), and has been exposed to battle type bots since she was born. While she is not competitive, she enjoys the sport and still loves driving her fun star-shaped robot.

In the semifinals of the Beetleweight class,



FIGURE 6. Starbot driven by Samantha Farrow of Team Death by Monkeys with father (Rob) and sister (Rebecca) providing encouragement.

TABLE 1. WINNERS.

1st:	Antweight Velociraptor Team DinoBots - Dawson Brown	Beetleweight Raptor 2.2 Team DinoBots - Dawson Brown
2nd:	Chewtoy Team Dawg - Matt Hall	Wobble Wopper Gausswave - Rob Purdy
3rd:	N/A	Allosaurus Team DinoBots - Doug Brown

Allosaurus had to fight against Team Dinobots' robot Raptor 2.2. While Raptor managed to beat his own teammate in this unfortunate matchup,

Allosaurus still placed third in the Beetleweight class, and was able to dish out some damage to robots like Scram and Pugly in its first competition.

Raptor 2.2 (**Figure 7**), the first ranked Beetleweight robot in the world built by Team Dinobots and piloted by 14 year old driver Dawson Brown, walked away with first place this competition. There were some tough fights along the way — including having to fight against teammate and new robot Allosaurus in the semifinals.

In the finals, it was a war of the wedges with reigning champ Raptor 2.2 and rebuilt wedge Wobble Wopper. It was a close match, but in the end Raptor's speed and agility let him outmaneuver Wobble Wopper and toss him in the pit to take first place at the 2012 Seattle Bot Battles. **SV**

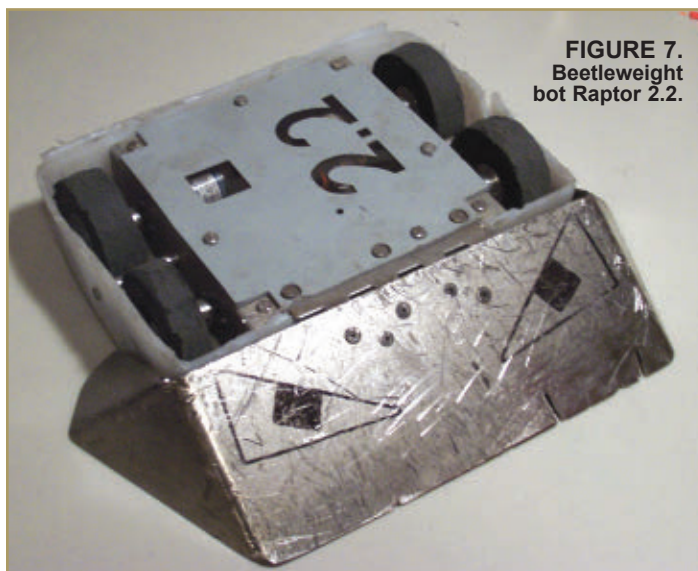


FIGURE 7. Beetleweight bot Raptor 2.2.

Mecha-Mayhem Moves to Cleveland

● by Dave Graham

The fall of 2012 posed a challenge for the members and supporters of the Chicago Robotic Combat Association (CRCA). The previous five years, CRCA had sponsored an Insect class fighting robot competition called Mecha-Mayhem at the International Hobby Exposition (iHobby) in the Chicago suburb of Rosemont, IL. This year, iHobby was moving their event 370 miles east to Cleveland, OH.

The CRCA was founded by Brian Schwartz and Dan Toborowski in 2004 in hopes of creating a midwest Insect class fighting robot venue. The CRCA formation was in response to the Central Illinois Robotic Club (CIRC) downsizing their combat robot events and movement towards expanding their thinking robot activities.

Dan left for school shortly after CRCA was formed, and Brian became involved as a robotics advisor in the science and technology course at Glenbrook North High School near Chicago. Students were working on a year-long project to build Insect class fighting robots. Dave Miller was a student at Glenbrook North High School, and joined Brian and the CRCA in 2005.

Together, Brian and Dave built a high quality, state-of-the-art eight by eight by four foot steel arena enclosed with Lexan and sporting four 120 psi pneumatic hammers in the arena corners. They also designed and built computer-controlled driver start/tap-out buttons, sequenced starting lights, and a match timer.

The arena debuted in 2005 at Glenbrook North High School where



FIGURE 1. Group shot of Team CRCA: back, Jen and Brian Schwartz; front, Erin Grondin; center Zoe Schwartz; and right Dave Miller.

the pair held a fighting robot demonstration for the school. Immediately following that demonstration, the arena was disassembled and moved to Minneapolis, MN for the Minnesota Twin Cities Mechwars 8.

The arena was also used for Mechwars 9 and 10 in 2006 and 2007, and for an event at the Mall of America in 2008. Early in 2007, CRCA was contacted by the Chicago Area Robotics Group (ChiBots) about bringing robot combat to their annual event held at the iHobby Expo in Rosemont. It was an opportunity too good to pass up, and a new partnership was formed.

As a result, CRCA's new Insect class fighting robot event — Mecha-Mayhem — was born. Both the CRCA/

iHobby partnership and Mecha-Mayhem continue to this day.

In the fall of 2012, Team CRCA was four and a half people strong, and faced with a 370 mile challenge if they wanted to hold their sixth Annual Mecha-Mayhem in October at the iHobby Expo in Cleveland. Team CRCA took the challenge, packed the arena, and headed east.



FIGURE 2. CRCA founder Brian Schwartz.



FIGURE 3. Announcer Jen Schwartz.



FIGURE 4. Handyman Dave Miller cleaning the arena after the demo bots destroyed all the junk electronics.



FIGURE 5. Handywoman Erin Grondin working the brackets during the competition.

On Friday morning, founder Brian Schwartz, his wife Jen, and their younger daughter Zoe posed in the arena in Cleveland with CRCA partner Dave Miller and his girlfriend Erin Grondin (**Figure 1**).

Meet the Mecha Minds

Brian (**Figure 2**) is 29 years old and has been involved in designing, building, and competing with fighting robots for the past decade. He still competes, but now favors organizing Mecha-Mayhem which is one of the best Insect class fighting robot events in the country.

When not tending to CRCA, Brian works as an engineer for Automated Manufacturing Solutions

(AMS) in Chicago.

As the CRCA founder, he provides oversight of all CRCA events, coordinates logistical support with the iHobby event organizers, arranges transportation for the arena, transportation and lodging for Team CRCA, engineers systems in support of the arena, and designs and manufactures Mecha-Mayhem trophies.

He and his wife Jen enjoyed a long courtship and tied the knot two years ago. They have two daughters: eight year old Adrianna (who couldn't make it to Mecha-Mayhem because of school) and 14 month old toddler bot Zoe.

Jen is also 29 years old and is employed as a social worker in the

Chicago area. At Mecha-Mayhem, you'll find Jen making supply and food runs during the arena set-up, and in a headset during the event working the crowd and providing live commentary of the matches for the audience (**Figure 3**).

Dave Miller is the 26 year old head of applications and tech support for ShopWare Incorporated — the MasterCam reseller for Illinois and Wisconsin. Dave built his first robot at age 17 and is the CRCA handyman responsible for ensuring registered robots meet safety requirements, the arena is clean and operable, and for the design and manufacturing of the Mecha-Mayhem trophies. Dave spends a lot of time in the arena taking



FIGURE 6. Fourteen month old toddler bot Zoe Schwartz eating pizza at the builder's dinner.



FIGURE 7. Mecha-Mayhem 2012 layout at the iHobby Expo in Cleveland, OH.



FIGURE 8. Pretzel Robotics father and son team Warren and Glenn Purvin, and their Antweight and Fleaweight bots.



FIGURE 9. Chris Olin in his blue Rock'em Sock'em robot costume picking on an eight year old.

pictures and cleaning up after the six, 12, and 15 pound demo bots destroy junk electronic components (**Figure 4**).

Erin Grondin is 23 years old and recently graduated from Aurora University with a Bachelor degree and plans to continue her education specializing in physical therapy. Erin is the CRCA handywoman, assisting virtually everyone accomplish their tasks. Erin also registers all combatants and manages the winner and elimination brackets during the event (**Figure 5**). She and Dave enjoy their on-going four-year relationship. Erin's mother Connie provides the CRCA custom embroidered shirts for Mecha-Mayhem.

Finally, toddler bot Zoe stayed busy eating a record 4,389 Fruit Loops and messing 47 diapers. Zoe was at her best eating pizza at the Saturday night builders dinner (**Figure 6**).

Why You Should Make it to Mecha

Rather than trying to explain all the great things about Mecha-Mayhem, here are my top 10

reasons you should attend:

Number 10: The robot combat area for Mecha-Mayhem was right by the east vendor entrance, making it easy to park and unload your bots, and repair parts. Gone was the noisy model tractor pull area. There was plenty of space for the arena, pits, big screen display, and spectator bleachers (**Figure 7**).

(Did I mention the free drinks and snacks for the competitors?)

Number 9: Creative team pictures — you might even get your picture in *SERVO Magazine*! Dave Miller climbed into the arena to take pictures of competing teams and their bots. The Pretzel Robotics father and son team of Warren and Glenn Purvin and their destructive



FIGURE 10. Gene Burbeck and his trio of demo bots — from left to right: 12 pound Dragonfly, Beetleweight Melty Brain, and Mantisweight bot One Fierce Weed Whacker.

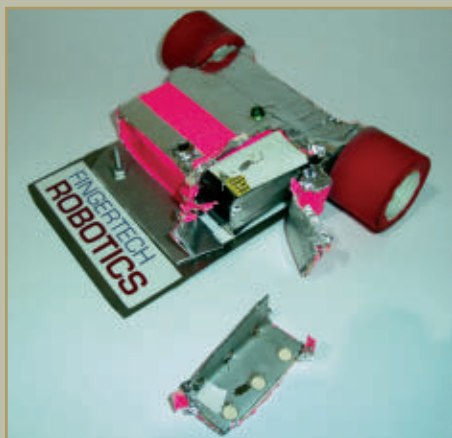


FIGURE 11. Damage to Fleaweight bot Little Red Riding Hood after a match with Demise.



FIGURE 12. Builders and their families at the Saturday night builder's dinner.

bots Antweight bot Vile Ant, Fleaweight bot Demise, and Antweight bot Low BLOW posed for Dave (**Figure 8**).

Number 8: See my good friend Chris Olin of the Ohio Robotics Club and event organizer for the House of Robotic Destruction (HORD) dress up like the blue Rock'em Sock'em robot. Chris is a long-time fighting robot enthusiast and a true showman.

He can often be heard during matches taunting his opponents with his own dry commentary, including his classic lines, "I can beat you with one arm" (used while his one arm lifter Fleaweight bot Lefty is fighting), or "Bad robot" (heard

when he uses the lifter on one of his three bots to spank his opponent), or better still, "It's only a flesh wound" (his last resort when his bots are dismembered or begin smoking).

Chris really outdid himself this time dressing up in the Rock'em Sock'em costume. Or, at least until the eight year old he was tormenting clocked him below the belt and brought him to his knees (**Figure 9**).

Number 7: The demo bots are awesome. Each year, the CRCA invites competitors with bigger bots to bring them to the event and demonstrate their destructive power by obliterating junk electronic

components, including printers and the like. This year didn't disappoint as Adam Carlson brought his 15 pound beater bot Chucker and Gene Burbeck brought a trio of destructive machines including six pound Mantisweight bot One Fierce Weed Whacker; his newest creation, a three pound melty brain bot; and 12 pound Dragonfly (**Figure 10**).

The melty brain wasn't quite operational, but Gene threw it in the arena for the Beetleweight rumble and invited the other combatants to take their best shot at the 5,000 rpm spinning beast. It was awesome!

Number 6: Damage is part of fighting robot competitions and



FIGURE 13. Brian Schwartz (left) and Dave Miller (right) with this year's custom trophies.

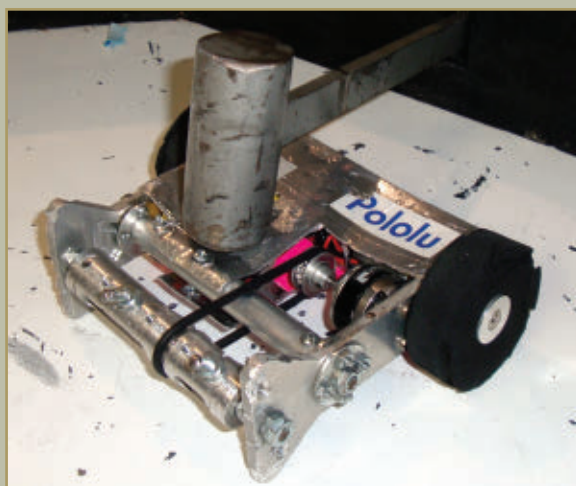


FIGURE 14. Arena hammer pounding Antweight bot Snaggletooth.



FIGURE 15. Group shot of Mecha-Mayhem competitors.

Mecha-Mayhem is no exception. Quite simply, if your opponent doesn't get you, the hammers will. In the case of my Fleaweight bot Little Red Riding Hood, my opponent Pretzel Robotics Fleaweight spinner Demise didn't want to go to grandma's house with me and tried to decapitate poor Little Red Riding Hood (**Figure 11**).

Number 5: CRCA sponsors a free pizza dinner on Saturday night for all the robot builders and their families. This is a tradition that goes back to the Mecha-Mayhem days in Chicago when Brian wanted to make sure everyone got a taste of real Chicago pizza.

The only difference is now builders and their families get a taste of real Cleveland pizza (**Figure 12**). Brian also uses the dinner to foster the friendship and camaraderie of the original BattleBots competitors.

Number 4: Great trophies and prizes have always been a part of Mecha-Mayhem. This year, Brian and Dave really outdid themselves creating custom colored, etched, illuminated Plexiglas trophies (**Figure 13**). The trophies combined

with prizes from event sponsors *SERVO*, FingerTech Robotics, and Dimension Engineering make Mecha-Mayhem one of the best awards events.

Number 3: The four 120 psi pneumatic arena hazard hammers that win their share of matches. The hammers were operated by randomly selected, impartial audience members with a lot of encouragement from both spectators and drivers. The hammers rendered my Antweight bot Snaggletooth inoperable after repeatedly beating it and forcing me to tap out (**Figure 14**).

Number 2: Registration is free and includes a four-day pass to the iHobby Expo. Had you entered one bot in each weight class that's easily a \$150 savings. The event organizers intentionally don't charge a registration fee to help those who might be financially challenged attend. However, CRCA does accept donations to help defray the cost of Mecha-Mayhem.

Number 1: Meet fighting robot enthusiasts and their families. Many of the nation's top competitors attend Mecha-Mayhem. In addition to the CRCA event organizers, I'm

talking about HORD's always tough Chris Olin; Team One Fierce's Gene Burbeck who has won events from Motorama in Harrisburg, PA to RoboGames in San Mateo, CA; Thomas Kenney who simply drives his over-powered bots so well you'd better not blink during the match or it's over; young upstart Warren Purvin of Pretzel Robotics who gets better with each event, is already the reigning Antweight champion in multiple events, and broke into the Fleaweight category with a win at Mecha-Mayhem this year; and my PennBots buddy Richard Kelley who is usually the elder competitor, yet always finds a way to the winner's circle.

They're all great people, always willing to lend you a hand. All the Mecha-Mayhem competitors paused after the driver's meeting for a group photo (**Figure 15**).

Mark your calendars now for mid-October 2013 and plan to attend the 7th Annual Mecha-Mayhem held in conjunction with the iHobby Expo at the IX Center in Cleveland, OH. You'll have a ball! You can follow the CRCA on their webpage or on their Facebook page. **SV**

GO MOD WITH YOUR MOBILE

by Fred Eady

Hollywood's collection of science fiction robots could do it all. Their fantasy mechanisms could walk, talk, think, and fight. Most all of, the first generation silver screen metal men were space travelers. They called a planet other than Earth their home. In 1951 in the movie *The Day The Earth Stood Still*, Gort arrived via an extraterrestrial flying saucer in Washington, D.C. In 1956, Robby the Robot found his residence on the *Forbidden Planet*. In 1965, it was the beginning of a series of planet hops for the robot of *Lost in Space*.

The aforementioned droids were smart and powerful. However, they all lacked something that we today consider a very important robotic part: a microcontroller. Robot was a lost mechanical pup roaming the galaxy seven years before the first earthly microcontroller was invented. Since Gort and Robby were not from this world, we don't know if their frames contained a microcontroller or not. These days, it's not uncommon to find a number of microcontrollers spinning electrons within a single robotic device.

Modularbotics

Do you remember seeing Dr. Smith or one of the Robinsons "deactivate" Robot by removing some type of module? What that says to me is that despite being B.M. (Before Microcontroller), Robot of *Lost in Space* was modular. That same modular concept that applied to Robot applies to the bots that you build.

Let's walk through a typical modularbotic design process. You want to build a mobile robot that is aware of its location and always knows the time of day. In addition, this particular robot is also a weatherman of sorts as it has the ability to sample the temperature at its current location. The robot's location at any particular time and the location's temperature are logged to a microSD card which is an integral part of the robot's fabric.

Keeping the time of day by a robot's watch normally entails selecting a real time clock IC that is compatible with the robot's host microcontroller. Another timing method to consider is the

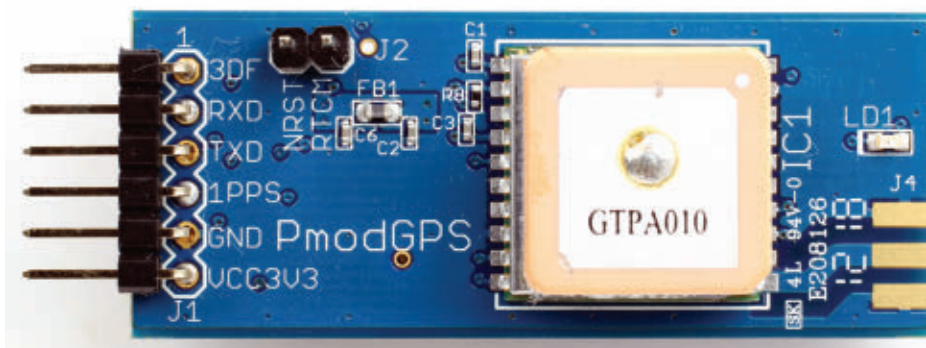


PHOTO 1. We can always have access to location and time of day by simply incorporating this Digilent PmodGPS module into our modularbotic design.

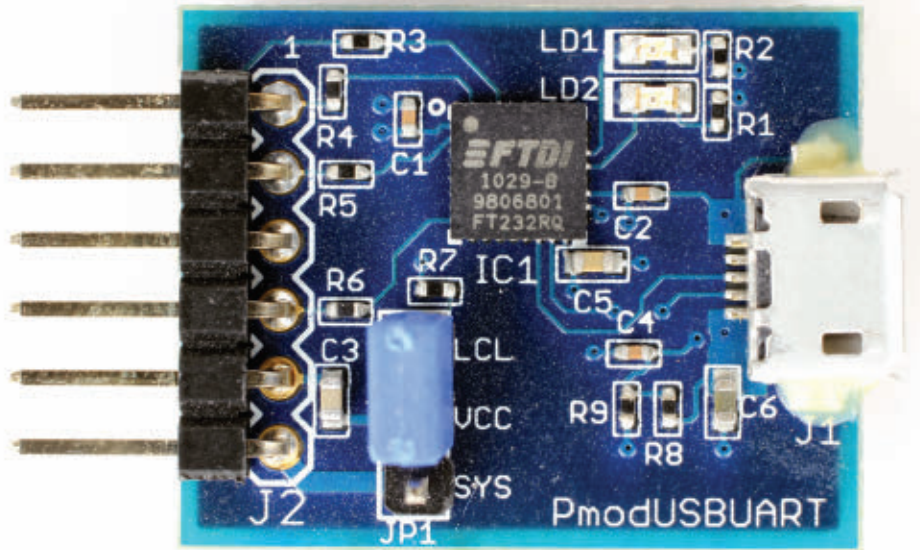
PHOTO 2. This little puppy seems to find its way into more and more of my projects. The PmodUSBUART is like Uncle Ben is to rice, Aunt Jemima is to pancakes, and Colonel Sanders is to fried chicken.

microcontroller's internal clock subsystem. Many of today's new PIC microcontrollers contain an embedded RTCC (Real Time Clock Calendar) which only requires an external 32.768 kHz tuning fork crystal and its associated capacitors. Two PICs with onchip RTCCs that instantly come to mind are the PIC18F46J13 and its big brother the PIC18F47J13. The PIC18F46J13 and PIC18F47J13 are identical with the exception of the PIC18F47J13's larger amount of program Flash memory. The downside to using an RTCC of any kind in this situation is that you have to initially set the time and hope your mechanical creation's batteries don't fall of the cliff.

Okay. We have decided to base our wannabe weatherman robot on the PIC18F46J13. However, we still have time of day and location requirements to fill. Since our temperature-taking robot also has to know where it's taking that temperature reading, the location requirement can only be filled by utilizing satellites. If you were to have asked Robby the robot to verify his location, he would have probably pulled out his compass and scanned for landmarks as there were no GPS (Global Positioning System) satellites in Earth orbit in his day. Robby couldn't use the cellular network to triangulate his position, either. As you well know, cell phones were not in every pocket in the 1950s. Using the GPS module

you see in **Photo 1**, we can satisfy both our location and time of day requirements.

The Digilent PmodGPS module takes all of the pain out of implementing GPS features into a robot. The PmodGPS speaks ASCII though a standard three-wire UART interface. The ability to run on the same voltage rail as the PIC eliminates the need for any extra level shifting circuitry between the PIC's



UART and the PmodGPS. The PmodGPS draws a bit over 30 mA when in acquisition mode. The power consumption drops to about 24 mA when a fix is acquired. If we are to write code to support the PmodGPS, it would be advantageous to see it in action. Power consumption is a very important factor in battery-powered robotic applications. So, I pulled out a Digilent Electronics Explorer to monitor the power consumption and a PmodUSBUART to help monitor the NMEA (National Marine Electronics Association) sentences.

Those of you that follow my editorial offerings in *SERVO* and *Nuts & Volts* (thank you!) know that my favorite Pmod is the PmodUSBUART, which I've visually captured for you in **Photo 2**. I assembled the basic GPS system on the Electronics Explorer's solderless breadboard. **Figure 1** details the electrical connections. The FTDI FT232RQ — in

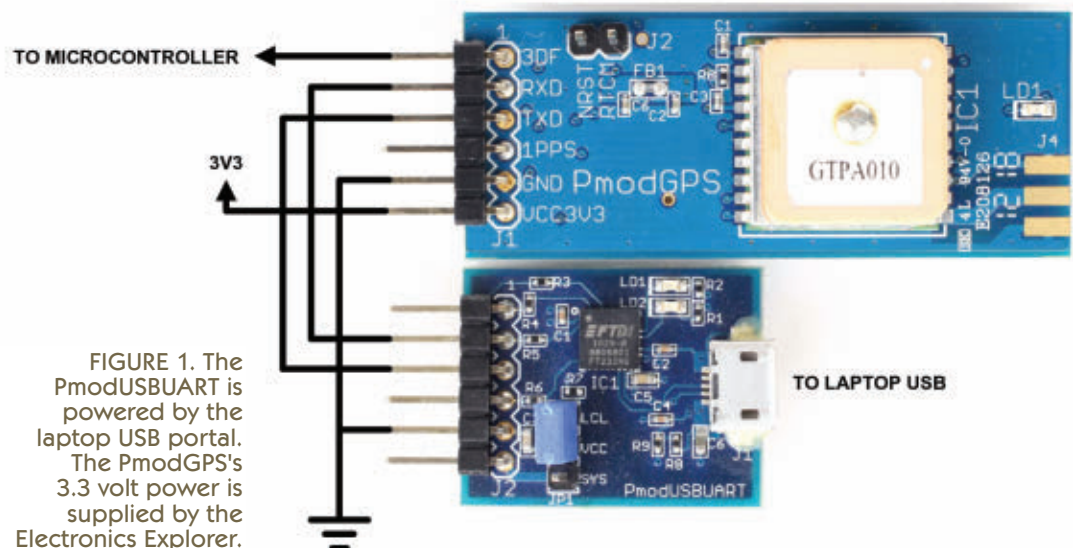


FIGURE 1. The PmodUSBUART is powered by the laptop USB portal. The PmodGPS's 3.3 volt power is supplied by the Electronics Explorer.

conjunction with its laptop-based drivers — forms a virtual COM port. An LED on the PmodGPS blinks at 1 Hz to signal that a fix is yet to occur. A fix has been established when the LED extinguishes.

The PmodGPS's 3DF pin drives the fix LED. The 3DF pin can also be used by a host microcontroller to determine fix status. Once a fix occurs, the NMEA strings flow from the PmodGPS into the PmodUSBUSART which is displayed in a Tera Term session running on the laptop. According to the Electronics Explorer, the PmodGPS drew about 32 mA following a power-up cold start. Once a fix was acquired, the PmodGPS current consumption dropped to the level you see in **Screenshot 1**. The PmodGPS has no low-power mode. To conserve power, it must be powered off.

A coin cell holder resides on the opposite side of the PmodGPS's circuit board. When the coin cell holder is populated with a battery, the PmodGPS can be powered down without losing any recent fix and time information. Without a coin cell in place, it would have to cold start with every power-up cycle. Cold starts typically take 35 seconds compared to one second for hot starts. If the PmodGPS is powered down for more than a couple of hours, a warm start is executed at power-up. Warm starts are 33 seconds in length.

Getting a Fix

The PmodGPS NMEA sentences begin with a dollar sign (\$) character, which is followed by five characters of talker ID and arrival alarm. The letters *GP* comprise the talker ID. The remaining three characters identify the sentence output descriptor. All of the following fields of GPS-related information are comma delimited. NMEA sentences emitted from the PmodGPS look like this:

```
$GPGGA,171443.000,2821.8352,N,08040.3724,W,1,6,1.28,2.2,M,-31.1,M,,*62
```

```
$GPGSA,M,3,05,17,04,10,12,02,,,,,1.60,1.28,0.96*0A
$GPGSV,2,1,08,10,69,062,29,02,56,321,12,05,47,208,31,12,44,294,19*7B
$GPGSV,2,2,08,04,42,041,28,17,31,109,31,13,13,068,,34,,,*4B
$GPRMC,171443.000,A,2821.8352,N,08040.3724,W,0.14,159.70,231112,,,A*7E
$GPVTG,159.70,T,,M,0.14,N,0.25,K,A*35
```

Let's break down the RMC sentence (\$GPRMC). The RMC sentence contains time, date, position, course, and speed data. The RMC sentence contents can be described as the recommended minimum navigation information. The first data field contains the UTC time formatted as hhmmss.sss. The A indicates that the data in the sentence is valid. Latitude information follows the validation character and is interpreted as ddmm.mmmm. Latitude is measured North or South of the Equator and the *N* denotes North. Longitude data is contained in the next comma-delimited field and is represented as dddmm.mmmm. Longitude associates East or West and that's what the *W* tells us.

The PmodGPS on the bench is not in motion. So, the course and speed data really does nothing for us here. The next piece of valuable information is the date formatted as ddmmyy (231112). The final A defines the mode, which is autonomous. The sentence checksum is always preceded with a '*' character and is always followed by a carriage return/line feed character sequence. The NMEA sentence structures are laid out in the PmodGPS reference manual.

Now that you have been introduced to the NMEA layout of an RMC sentence, you'll notice that you can get the same time, latitude, and longitude data from the GGA (Global Positioning System Fix Data) sentence.

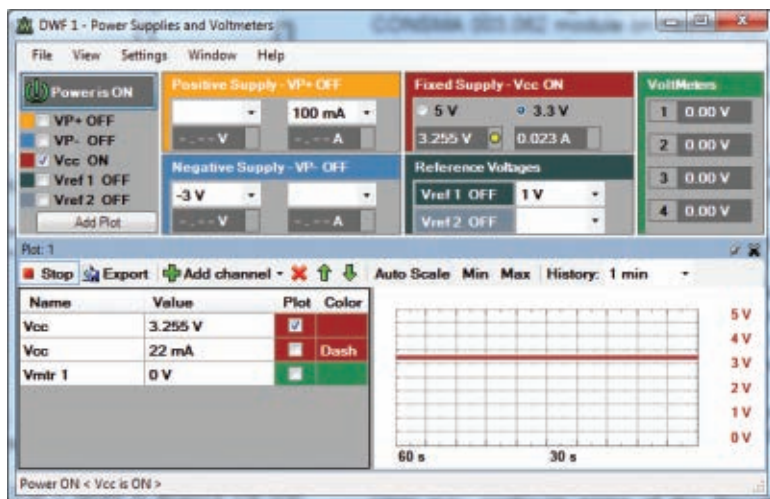
Acquiring the Data

Knowledge of the structure of the NMEA sentences provides a basis for the code to acquire them. Each of the NMEA sentences contain less than 100 characters. At this point, we have plenty of microcontroller SRAM to spare. So, we can start by allocating five 128-character arrays. That's one array for each sentence type:

```
char gpsbuf0[128];
char gpsbuf1[128];
char gpsbuf2[128];
char gpsbuf3[128];
char gpsbuf4[128];
BYTE bufcntr;
```

The *bufcntr* byte will point at the buffer to be used for the next NMEA sentence. The idea is to constantly capture GPS sentence data and store it in the sentence buffers. A dollar character (\$) delineates the beginning of every NMEA sentence. A carriage return/line feed sequence (0x0D, 0x0A) signals the end of every NMEA sentence.

So, all we have to do is look for a dollar



SCREENSHOT 1. The PmodGPS is based on the Global Top Gms-u1LP. The Gms-u1LP is fitted with an internal switch mode power supply that reduces power consumption by 30%.



PHOTO 3. This temperature probe can be subjected to harsh environments. The ENV-TMP's watertight construction allows it to swim. Thus, it's perfect for monitoring the temperature of just about any liquid.

character and stuff every incoming byte into the selected sentence buffer until we encounter 0x0A.

If everything goes right, a single sentence will be placed in the targeted buffer. Once the sentence is captured, it can be identified by the three characters that follow the talker ID (GP). The fields are set for each sentence type, and we can simply parse the sentence to obtain the information we want to work with. I assembled the sentence buffer code using the C *switch* directive:

```
bufcntr = 0;
while(1){
    switch(bufcntr)
    {
        case 0:
            i = 1;
            while(!(CharInQueue()));
            data_in = recvchar();
            if(data_in == '$')
            {
                gpsbuf0[0] = data_in;
                do{
                    data_in = recvchar();
                    gpsbuf0[i++] = data_in;
                }while(data_in != 0x0A);
            }
            if(data_in == 0x0A)
            {
                bufcntr = 1;
            }
            break;
    }
```

Initially, the *bufcntr* variable is set to zero, which points to the 128-character array *gpsbuf0*. It is not necessary, but we will do it here. We'll preserve the initial dollar sign character in the first element of each sentence array. That's why you see the *i* index pointer initialized to 1 instead of 0.

The *CharInQueue* function blocks the execution of the program thread. However, the code that makes up the ISRs (interrupt service routines) is able to execute. Since we're prototyping the GPS data acquisition function, at this time we'll not write timer/iteration code around the *CharInQueue* call to force it to release and allow other code to execute. Plus, the PmodGPS is streaming in serial data to the PIC18F46J13's USART every second.

Once the USART interrupt handler detects and buffers an incoming character, we use the *recvchar* function to pull a character from the tail of the *USART_RxBuf* array. If the character we pulled from the receive buffer array happens to be a dollar sign, we continually pull characters from the receive buffer until we encounter a linefeed character (0x0A).

Upon the arrival of the linefeed character, we set the *bufcntr* to point at the next *gpsbufx* array. We continually perform this process for each of the five *gpsbufx* arrays. Here's the code for populating the second sentence buffer:

```
case 1:
    i = 1;
    while(!(CharInQueue()));
    data_in = recvchar();
    if(data_in == '$')
    {
        gpsbuf1[0] = data_in;
        do{
            data_in = recvchar();
            gpsbuf1[i++] = data_in;
        }while(data_in != 0x0A);
    }
    if(data_in == 0x0A)
    {
        bufcntr = 2;
    }
    break;
```

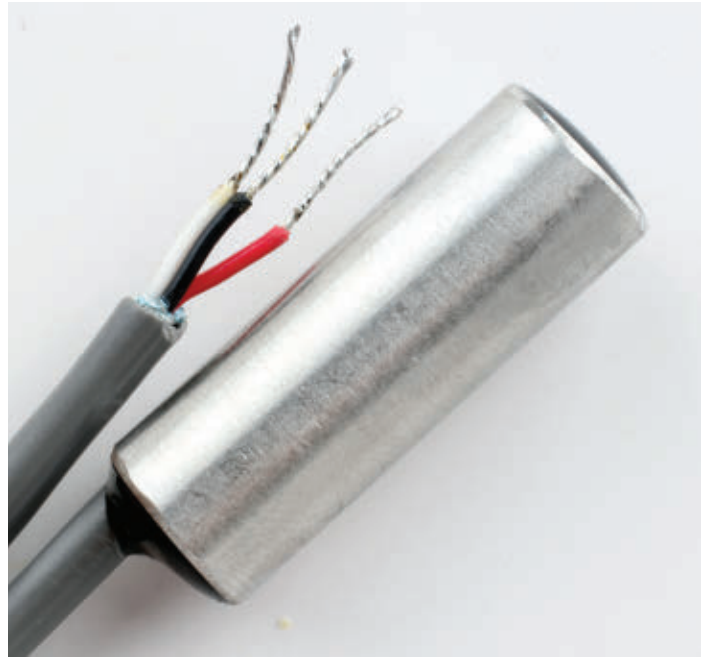
A Rugged Robotic Temp Sensor

I normally employ the services of a Senserion temperature/humidity sensor for embedded applications. However, this is a robotic application. So, the temperature sensor I've selected is fit attire for a roving mechanical meteorologist. The business end of the Atlas Scientific ENV-TMP is posing for us in **Photo 3**.

The ENV-TMP is a breeze to use. All we have to do is supply power to the probe and pick up the temperature data with the microcontroller's analog-to-digital converter (ADC). The red and black wires are the power connections. The ENV-TMP draws a mere 6 μ A.

With current consumption that low, we could use one of the PIC's I/O pins to power the temperature probe. The ENV-TMP's white wire will feed our microcontroller's 12-bit ADC. The temperature is gleaned from the ENV-TMP by converting the raw ADC count to millivolts.

Once we have a millivolt value, we can call upon the PIC18F46J13 to substitute it into the ENV-TMP's temperature formula as ADC_VAL:



Degrees Celsius = 0.0512 * ADC_VAL ? 20.5128

Naturally, we can easily convert the Celsius temperature value to Fahrenheit. I wrote a little diddy that reads the ENV-TMP, performs the Celsius calculation, and spits out both Celsius and Fahrenheit temperature values:

```
void getTemp(void)
{
    int1 done;

    set_adc_channel(0);
    delay_ms(10);
    read_adc(ADC_START_ONLY);
    done = adc_done();
    while(!done) {
        done = adc_done();
    }
    tempmv = read_adc();
    tempmv *= 0.805664;
    tempC = 0.0512 * tempmv - 20.5128;
    tempF = (1.8 * tempC) + 32;
    sprintf(tempbuf, "%3.1f", tempF);
    printf("Temp F = %3.2f \r\n", tempF);
    printf("Temp C = %3.2f \r\n", tempC);
}
```

The raw temperature count is stored in the *tempmv* floating point variable. The PIC's ADC is referenced to Vcc and GND, with Vcc coming in at 3.3 VDC. That puts each step of the microcontroller's 12-bit ADC at .0008056664 volts. We must convert the raw temperature count to millivolts to use the ENV-TMP's Celsius temperature formula. So, we multiply the ADC step voltage by 1,000 and multiply the new step voltage with the raw count value contained within *tempmv*.

Now, we're ready to plug our newly calculated *tempmv* into the ENV-TMP formula. The calculated Celsius temperature value is stored in the *tempC* floating point variable. Using the standard Celsius to Fahrenheit conversion formula (Degrees Fahrenheit = (1.8 * tempC) + 32), we compute a Fahrenheit temperature value and store it in the *tempF* floating point variable.

We can use the *sprintf* instruction to prepare the floating point temperature readings for insertion into an array. The *printf* instruction allows us to display or transmit the temperature data using the PIC18F46J13's USART.

Securing the Data

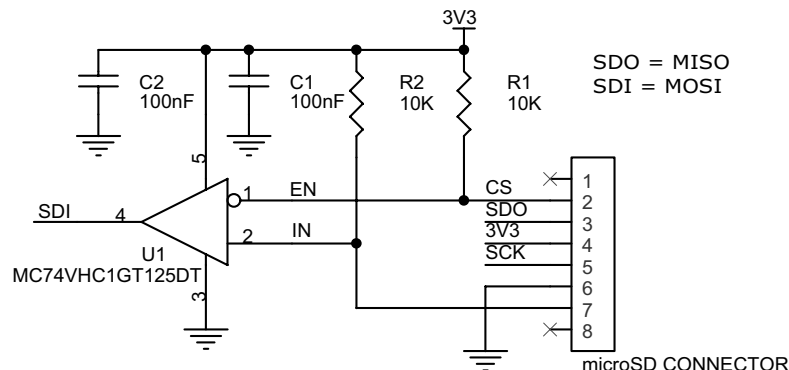
The data that emanates from the PmodGPS is Excel spreadsheet-ready. The commas that separate the data fields in the GPS sentences are used to place each data set in a spreadsheet cell. If we were to collect the GPS sentences into a file and name the file *gpsdata.csv*, Excel would open the file and automatically import the data into separate cells of a worksheet.

This type of file is called a Comma Separated Values file (CSV). We can also CSV-format our temperature data to match that of the PmodGPS.

I've already given you the hardware and firmware keys to the microSD card interface. I used the same EDTP microSD hardware interface that I described in detail in the December 2010 issue of *Nuts & Volts*.

The microSD hardware is close up and personal in **Photo 4**. The pairs of 10K resistors and 100 nF bypass capacitors that support the tri-state buffer IC are graphically depicted in **Schematic 1**.

In the December 2010 Design Cycle, I used the Microchip Application Libraries to construct the microSD firmware driver. If



SCHEMATIC 1. The tri-state buffer is optional. However, if you have several devices on the same SPI bus, it becomes essential.

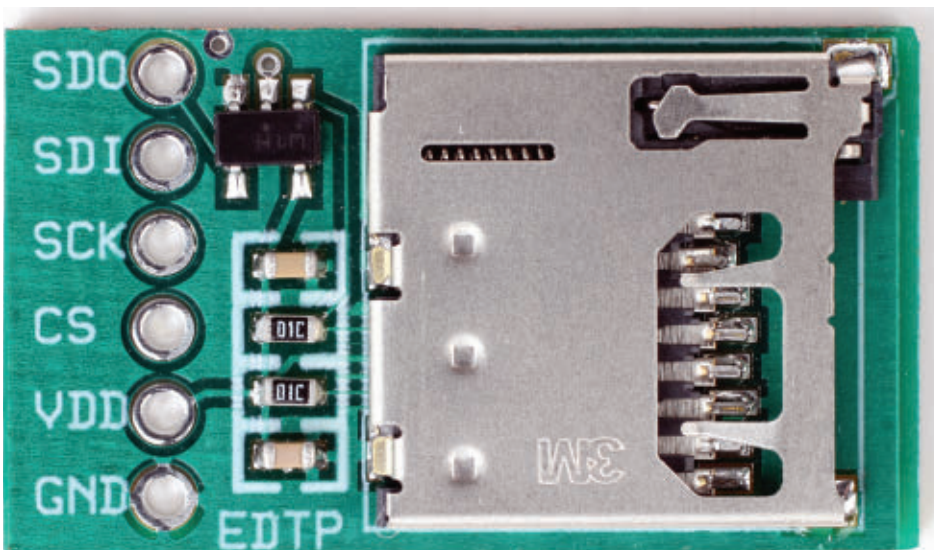


PHOTO 4. This simple little circuit also seems to fall into a bunch of my projects. It's a simple design that pays big benefits. This is a super easy way to add gigabytes of nonvolatile storage to your robot's electronic fabric.

you're a CCS C programmer, a very good microSD card driver comes as standard equipment with the CCS C compiler package.

Add Your Mortar

All you need is a microcontroller that can drive a SPI bus, along with a pair of USARTs. The first USART will service the PmodGPS. The second USART port can be used to feed a data radio. To measure the temperature, all you'll need is an ADC input port.

I've provided a microSD hardware circuit and access to the microSD driver firmware. You also have GPS data acquisition skeleton code and you have the code to process the ENV-TMP's temperature readings. All that's left to do is apply these tools to your modular robotic design. **SV**

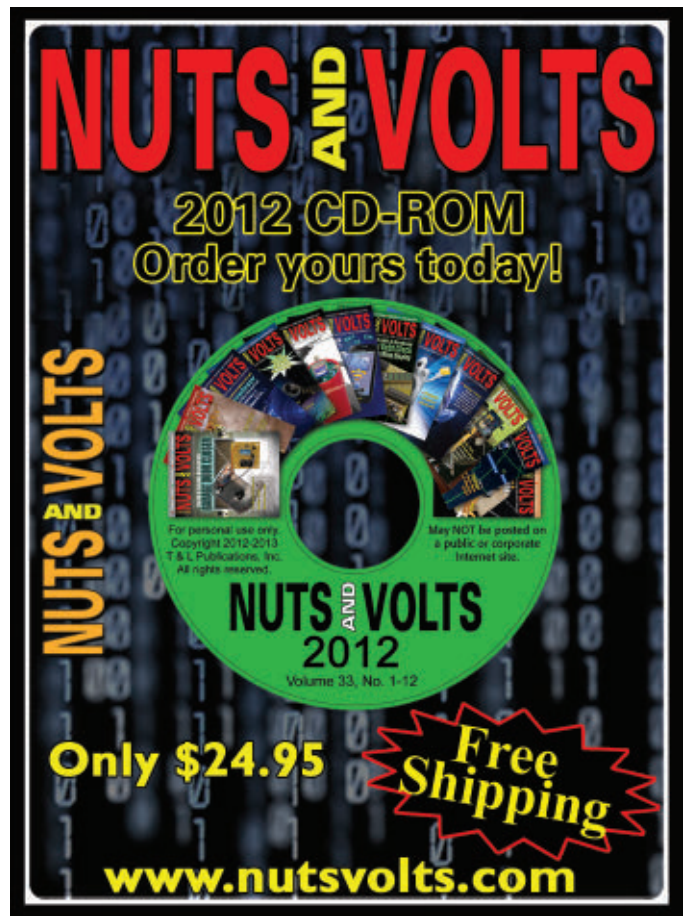
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Get the Most from XBee Transceivers

Small, ready-to-use wireless modules let you control motor speeds and actuators in robots. These inexpensive modules also have other capabilities that engineers, experimenters, and robot builders can take advantage of. The XBee Series-1 transceiver modules, for example, transfer digital and analog information, create networks of modules, go into power-saving sleep modes, and work with microcontrollers via a universal asynchronous receiver-transmitter (UART) port. I'll provide examples of how to use the XBee modules to help new bot builders get off to a good start.

by Jonathan A. Titus

You can use XBee modules as bare-bones wireless serial communication links to transfer information back and forth, perhaps to control a remote device or to report the state of digital and analog inputs from remote sensors. The XBee Series-1 modules that operate in the 2.4 GHz band have a maximum range of about 100 feet indoors and about 300 feet outdoors. The XBee Series-1 PRO modules communicate over longer distances.

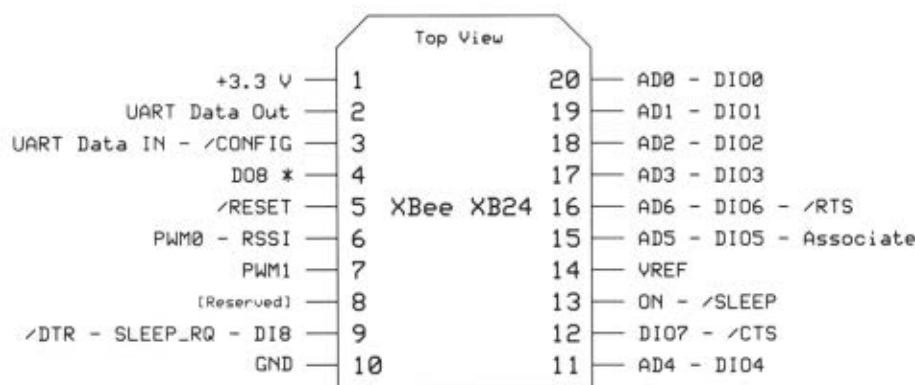
Each 20-pin XBee module provides seven digital and analog I/O pins; one digital only I/O pin; one digital input pin; and two pulse width modulation (PWM) outputs. Pins for serial communications (UART), power, and control use the remaining pins. The diagram in **Figure 1** shows a top

view of the XBee pin numbers and signal abbreviations.

The XBee pins have a 2 mm center-to-center distance, so you might need adapters that route the signals to pins on 0.1 inch (2.5 mm) centers. Both Parallax (part no. 32403; \$2.99) and SparkFun Electronics (part no. BOB-08276; \$2.95) sell these adapters. (SparkFun pins and contacts are sold separately.) To fully take advantage of XBee capabilities, you must change some internal settings. Don't worry; you can always get back to factory-default settings.

Digi International offers free PC software (X-CTU) that simplifies working with XBee modules. Download the X-CTU software at www.digi.com/support/productdetail?pid=3257&type=utilities. I recommend you also download and print a copy of the 68 page Digi manual (*XBee/XBee PRO Modules*) from http://ftp1.digi.com/support/documentation/90000982_H.pdf.

I use an XBee-to-USB adapter, so my lab PC can change module settings as well as transmit and receive information among XBee modules. Both Parallax (part no. 32400; \$23.99) and SparkFun (part no. WRL-08687; \$24.95) sell these USB adapters, as well.



* DOB not supported at this time.

FIGURE 1. Pin locations, numbers, and functions for an XBee XB24 Series 1 module.

Example 1: How You Use the X-CTU Software

Before you start the X-CTU software, always place an XBee module in a USB adapter and connect the adapter to your PC. I found the X-CTU software will not recognize an XBee-to-USB adapter unless you plug it in first. The X-CTU program opens a window similar to that shown in **Figure 2**.

If you see the error message "Invalid class string" when you start the X-CTU software, just click on OK. Note the four tabs: PC Settings, Range Test, Terminal, and Modem Configuration. For whatever reason, Digi calls the XBee modules "modems." Click on the PC Settings tab and in the Select Com Port window, choose the USB Serial Port (x) that represents your XBee-to-USB adapter. (My lab PC set the USB adapter at COM3 as shown in **Figure 2**.)

Next, check the settings along the right side of the window to ensure you have the following: Baud 9600, Flow Control NONE, Data Bits 8, Parity NONE, and Stop Bits 1. If not, change these settings to match those above. With your XBee module connected, click on Test/Query. You should see another window of information as shown in **Figure 3**. If you do not see this result, click on Retry. If you still don't see this information, check your USB-to-XBee adapter, USB cable, and COM port assignment.

Write down the serial number for your module and then click on OK. (Your serial number won't match mine.)

Click on the X-CTU Terminal tab to open a window for communications with the attached XBee module. The Terminal can send AT-type modem commands to a module and display any responses. To start the command mode, you will type three plus signs (+++) and wait for the module to respond with OK. Do not press the keyboard [Enter] key after the +++.

After you see the OK reply, you have 10 seconds in which to type a command – and data, if any – followed by the [Enter] key. If you wait more than 10 seconds, you must type +++ again and wait for OK. Go ahead and type +++, wait for the OK, and then type ATSL and then [Enter]. This command causes the module in the USB adapter to reply with the lower four bytes (SL) of your module's eight-byte serial number which you saw during the Test/Query operation. My XBee module showed the hexadecimal value 4049E028.

Type +++ again, wait for the OK, and type ATSH followed by [Enter]. This command retrieves the high four bytes (SH) of the module's serial number. For my module, it is 13A200. The ATSH response

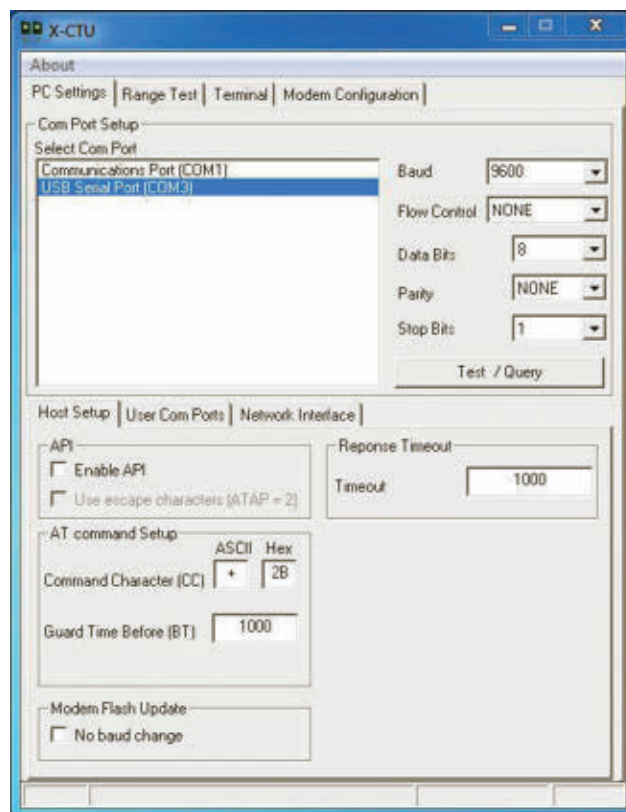


FIGURE 2. X-CTU display at software start-up.

suppresses leading zeros, so the module actually has SH = 0013A200. The manual referred to earlier lists all the two-letter AT-type commands and any data they might need. These AT commands provide an easy way to test an XBee module attached to your computer and perform basic operations.

Next, click on the Modem Configuration tab to open a window that will show all settings available in an XBee module. When you first use X-CTU, this window will appear blank. In the small section labeled Modem Parameter and Firmware, click on Read to get the current settings from an attached XBee module. Under the Networking & Security

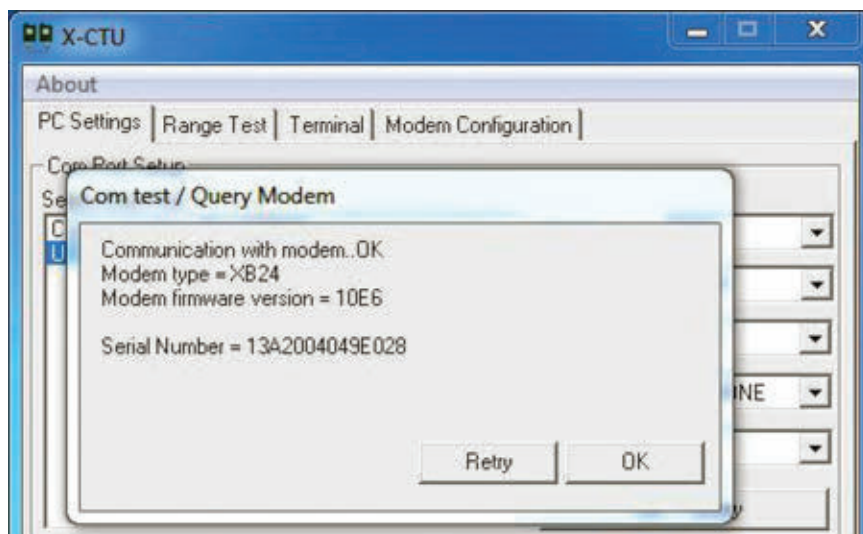


FIGURE 3. Testing communications with an XBee module provides information about the module attached via a USB-to-XBee adapter.

section, you will see the SH and SL values obtained earlier with the ATSH and ATSL commands in the Terminal window. You will change other settings through a menu of choices or by keying in a value.

After you make changes in the Modem Configuration window, click on Write to load them into your XBee module. To return an XBee module to its “factory fresh” settings, click on Restore. I recommend you “restore” a module when you change settings to ensure you start with all parameters returned to their default states. Then, click Read to obtain the default information.

Example 2: How to Set Up Digital I/O Communications

Suppose you have a remote device (an LED, motor-drive, solenoid, and so on) you want to control with XBee. Before two XBee modules can communicate, they must know each other’s identity. You could use the eight-byte serial number, but XBee modules let you use “short” two-byte addresses instead. A Destination Low (DL) address identifies the destination of a transmission and a Source Address (MY) identifies the source of a transmission. You set those values via the X-CTU software.

For two XBee modules, I used the settings shown in **Table 1** which include other values I changed for my LOCAL and REMOTE XBee modules. The IA (Input Address) value

of FFFF, for example, lets information received by an XBee module change the state of its I/O pins. The Node Identifier (NI) lets you name each module. I recommend you also put a small label on each XBee module to easily identify them. My LOCAL and REMOTE labels indicate a module near my lab PC and one a few feet away powered with a separate supply or two 1.5 volt D batteries.

Local Module: The setting 3-DI (digital input) for the D3-DIO3 parameter on the LOCAL module sets the AD3-DIO3 input pin (pin 17) so it will accept a logic-1 or logic-0 input. A switch connected between this pin and ground will control the corresponding pin on the REMOTE module. The IR (Sample Rate) value determines how often the transmitter will sample the digital signal at the AD3-DIO3 pin, and the IT (Samples before Transmit) value sets the number of samples the transmitter will take before it transmits them. I set the Sample Rate to one second (3E8) and the Samples value to one. Thus, the transmitter takes one sample of the logic level on the AD3-DIO3 pin every second and transmits it. You can set the IT value as short as a few milliseconds if you want a faster response.

Remote Module: The REMOTE module has the same IA setting (FFFF). The D3-DIO3 setting of 5-DO HIGH for its AD3-DIO3 pin (shown in **Table 1**) causes this signal to act as a digital output. The HIGH designation places this output in the logic-1 state when the module receives power. This output corresponds to the AD3-DIO3 input on the LOCAL module. When the AD3-DIO3 output on the REMOTE module becomes a logic-0, the LED turns on.

If you have two XBee modules, change the configurations to those shown in **Table 1** for each module and connect them as shown in **Figure 4**. When you change the switch setting at the LOCAL module, the LED at the REMOTE module will turn on or off accordingly, but with a delay as long as one second. As an experiment, change the IR value for the LOCAL module to 100 hex for a faster response at the LED.

Each ADx-DIOx input has a “weak” pull-up resistor between the input and +3.3 volts. Thus, if you do not connect anything to a digital input pin, that pin goes into a logic-1 state. The XBee module enables the pull-up resistors by default. You can disable them if you choose by using a

PR command or through the PR settings in the Modem Configuration window. See the Digi XBee manual for details.

Note that in this example, the REMOTE module never transmits any information about its I/O pins back to the LOCAL module. In the next example, you will see how to use a remote module to initiate communications and transmit information to a local module.

Table 1. XBee module settings for a one-bit remote control.			
LOCAL		REMOTE	
DL	FE54	DL	12AB
MY	12AB	MY	FE54
D3-DIO3	3-DI	D3-DIO3	5 - DO HIGH
IT	1	IA	FFFF
IR	3E8	NI	REMOTE
IA*	FFFF		
NI	LOCAL		

*Look in the “I/O Line Passing” folder in the Modem Configuration window.

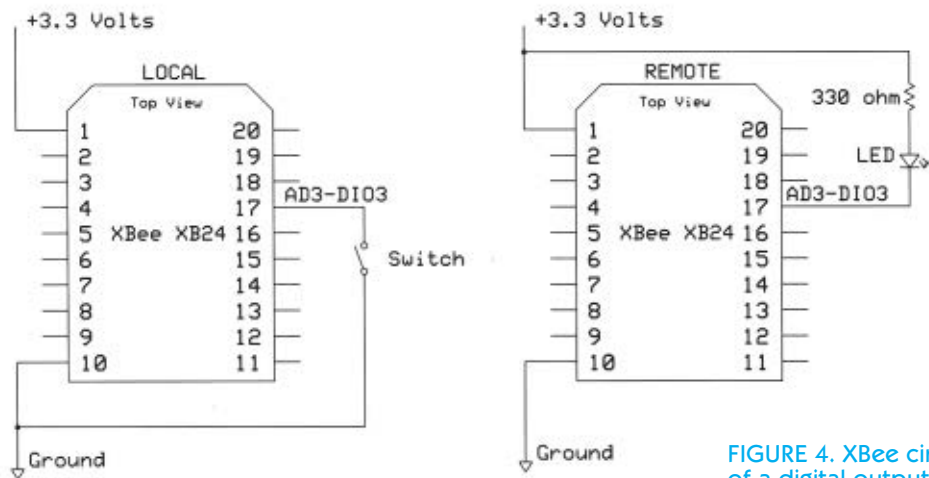


FIGURE 4. XBee circuit for remote control of a digital output.

Example 3: How to Use Analog I/O Communications

In addition to accepting logic-0 and logic-1 logic signals, the ADx-DIOx pins can handle analog voltages too, but with constraints. Each XBee module contains a 10-bit analog-to-digital converter (ADC) that “converts” a voltage into a 10-bit binary value. In hexadecimal, those values range from 000 to 3FF, or 0 to 1023 in decimal. Keep in mind that the ADC requires a reference voltage input at the VREF pin (pin 14). You could connect this pin to 3.3 volts, although a commercial 2.5 volt reference chip would work well too, and would give the ADC inputs a range from zero to 2.5 volts. The ADC input voltage can go from zero volts (ground) to as high as the reference voltage, VREF. The ADC input and the VREF input (pin 14) should never exceed 3.3 volts.

On a transmitting module, only the AD0-DIO0 and AD1-DIO1 analog input pins have corresponding “analog” outputs on a receiving module. Those two outputs – PWM0 (pin 6) and PWM1 (pin 7) – produce a pulse width modulation (PWM) signal. The PWM outputs have a fixed frequency of 16 kHz. The width of the pulse varies in direct proportion to the voltage on the corresponding AD0-DIO0 or AD1-DIO1 inputs at the transmitter.

These two PWM outputs have some quirks. If you sample the voltage at the transmitter’s AD0-DIO0 or AD1-DIO1 pins every few seconds and transmit the information every few seconds, the PWM output operates just fine. However, you cannot send only one analog sample and have the PWM output continue to produce the same signal forever. The PWM output stays active for only about 22 to 25 seconds.

If you drive an LED at your LOCAL module with the PWM0 or PWM1 signal, varying the voltage at the corresponding AD0-DIO0 or AD1-DIO1 input at your REMOTE module will vary the LED brightness. The settings shown in **Table 2** configure the LOCAL and REMOTE modules for this type of use. Note that the REMOTE module samples its

analog input (AD0-DIO0) once every two seconds (3E8 x 2). **Figure 5** shows the XBee module connections. If you need a voltage from an XBee PWM output, say PWM0, you can use a simple R/C circuit to filter the pulsing signal to give you a DC signal. This PWM0 output will correspond to the analog input at the transmitter’s AD0-DIO0 input. Again, every few seconds a transmitting module with an analog input must transmit – a “refresh” – the analog information to the receiving module with an active PWM output. Otherwise, the PWM output will cease after 22-25 seconds.

If only the AD0-DIO0 or AD1-DIO1 inputs at a transmitter have corresponding PWM outputs at a receiving module, what happens to the analog signals applied to a transmitter’s AD2-DIO2 through AD6-DIO6 pins? How do you get their 10-bit voltage values?

Table 2. XBee module settings for an analog input and PWM output.			
LOCAL		REMOTE	
DL	FE54	DL	12AB
MY	12AB	MY	FE54
P0-PWM0	2-PWM OUTPUT	D0-DIO0	2-ADC
IA*	FFFF	IT	1
NI	LOCAL	IR	7D0
		IA	FFFF
		NI	REMOTE
*Look in the “I/O Line Passing” folder in the Modem Configuration window.			

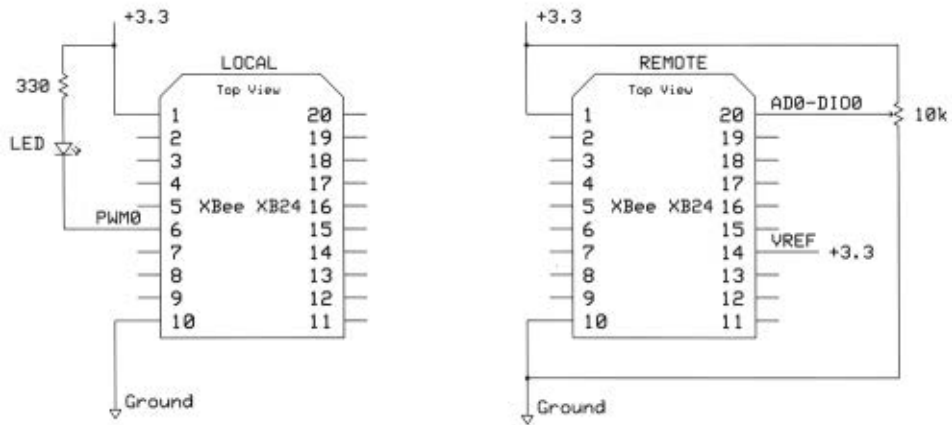


FIGURE 5. An XBee circuit that uses an analog input at a remote module to control a PWM output that drives an LED.

Example 4: How to Obtain ADC Values

If you set any of the AD2-DIO2 through AD6-DIO6 pins on an XBee module to measure voltages and transmit this information, the 10-bit ADC values appear in the serial output from the receiver’s UART Data Out (pin 2). A microcontroller can accept this serial data and software can process it to yield useful information. You also can view the data in the X-CTU Terminal window.

I set my REMOTE module to have an active digital input

at AD2-DIO2 (pin 18) and an active analog input at AD4-DIO4 (pin 11). A 10K ohm potentiometer provided a voltage that varied between ground and +3.3 volts, and a jumper served as my digital input “switch.” The REMOTE module took one sample every five seconds and transmitted it to my LOCAL module. The schematic diagram in **Figure 6** shows the electrical connections. To illustrate the communication of ADC data, I set the configurations shown in **Table 3** for my REMOTE and LOCAL XBee modules.

I programmed the settings in my REMOTE XBee

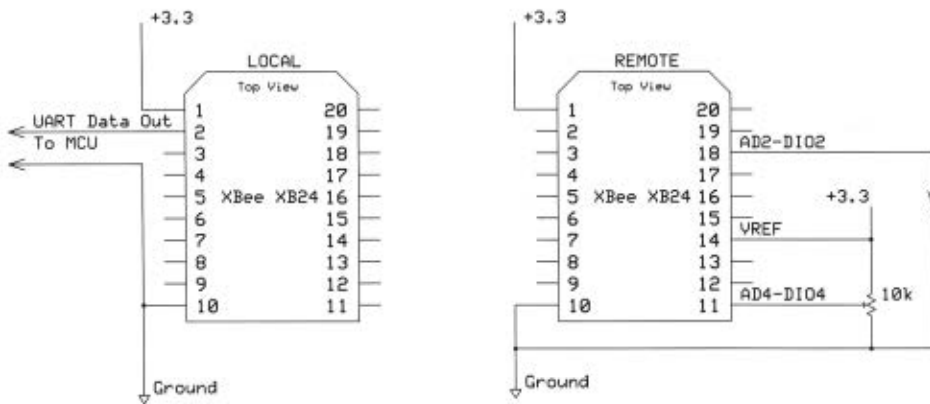


FIGURE 6. An XBee circuit that shows a remote module with one analog and one digital input. Received data comes out the UART pin and goes to a microcontroller or appears in a terminal window.

Table 3. Settings for remote transmission of analog and digital data.

LOCAL		REMOTE	
DL	FE54	DL	12AB
MY	12AB	MY	FE54
IA	FFFF	D2-DIO2	3-DI
NI	LOCAL	D4-DIO4	2-ADC
		IT	1
		IR	1388
		IA	FFFF
		NI	REMOTE

Table 4. A received series of bytes provides information from a remote module.

Bytes	Function
7E	Start of transmission (fixed value)
00 0C	Number of bytes in transmission (12)
83	Code for 16-bit module addressing (fixed value)
FE 54	16-bit address
46	Signal strength
00	Status byte (all OK)
01	Number of samples
20 04	Active signal bytes
00 00	Digital data bytes
00 00	Analog data bytes
BF	Checksum (calculated at transmitter)

module so I would see only one transmission.

Although this series of hex values might seem like nonsense, you can use the information in **Table 4** to interpret it. The number-of-bytes-in-transmission value (000C, or 12₁₀) refers to the highlighted bytes in **Table 4**. The table indicates my LOCAL module received one sample from an XBee module with the two-byte address FE54 — my REMOTE module. The active signal bytes indicate which analog and digital inputs are configured for the REMOTE module. You interpret these bytes as shown in **Table 5**.

The bits set for A4 and D2 reflect the settings I made for the AD2-DIO2 and AD4-DIO4 pins on my REMOTE module. The next two bytes in the received data represent the digital data followed by the analog data. At first, I had a logic-0 input at the AD2-DIO2 pin and a ground at the AD4-DIO4 pin. When I changed the digital input to a logic-1 and set the potentiometer about half way between its extremes, I saw the digital and analog bytes in the data from my REMOTE module as shown in **Table 6**.

The active signal bytes remain the same. The 00 04 indicates a logic-1 at the AD2-DIO2 pin on the REMOTE module (00000000 00000100) and a value of 01B1 from the ADC. Because I used a 3.3 volt reference for the ADC, I can convert this value into a voltage: 01B1 = 433₁₀ because the ADC has 1,023 voltage “steps;” the 433 value indicates the unknown voltage is at step 433. The proportion of 433/1023 yields about 0.42. Thus, the unknown voltage equals 0.42 times the reference voltage, 3.3 volts, or 1.4 volts. I measured the voltage at the potentiometer

independently with a DVM and found 1.44 volts. If you decide to take more samples for each transmission, you will see the data for each sample in this sequence:

Sample 1 digital data bytes
Sample 1 analog data bytes
Sample 2 digital data bytes
Sample 2 analog data bytes

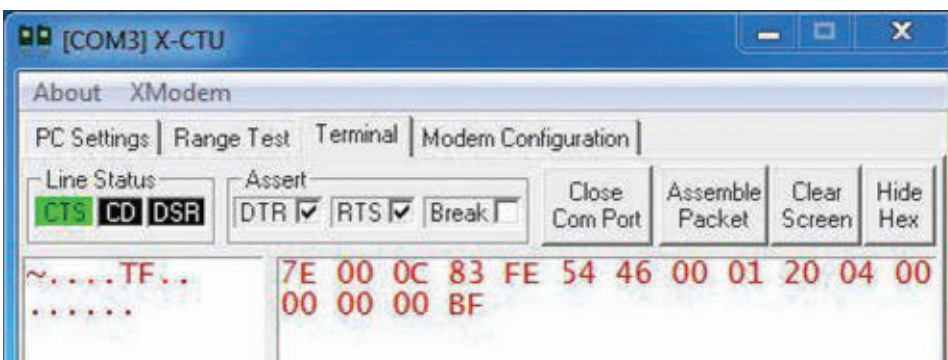


FIGURE 7. Information received from my REMOTE XBee module with an active digital and an active analog input.

If you have two analog inputs on a transmitter, the information follows this format:

Sample 1 digital data bytes
 Sample 1 analog data bytes for ADx-DIOx
 Sample 1 analog data bytes for ADy-DIOy
 Sample 2 digital data bytes
 Sample 2 analog data bytes for ADx-DIOx
 Sample 2 analog data bytes for ADy-DIOy

The lowest numbered ADx-DIOx analog values appear first, followed by values from higher numbered analog inputs in order. You will know which digital and analog inputs you have active, so you can use software to parse the received information to show on/off conditions for digital inputs at a remote module, as well as analog voltages and analog inputs. A microcontroller could parse this information and use it to display on/off conditions for inputs, display temperatures for remote sensors, and so on.

That's a Wrap

You also can control remote devices, set up networks of XBee modules, put modules into low-power sleep modes, and connect XBee modules with microcontroller boards such as the Arduino Uno, Digilent UNO32, ARM mbed, BeagleBoard, Raspberry PI, Parallax Propeller, and so on. These MCU boards can also create command packets to perform many interesting and useful network operations. **SV**

Table 5. Active signal bits in two bytes indicate active I/O pins.

First Active Signal Byte								
	First Hex Character				Second Hex Character			
Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Bit Function	X	A5	A4	A3	A2	A1	A0	D8
Data	0	0	1	0	0	0	0	0
Second Active Signal Byte								
	First Hex Character				Second Hex Character			
Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Bit Function	D7	D6	D5	D4	D3	D2	D1	D0
Data	0	0	0	0	0	1	0	0

Table 6. Changing the logic level and ADC input voltage gave these results.

20 04	Active signal bytes
00 04	Digital data bytes
01 B1	Analog data bytes

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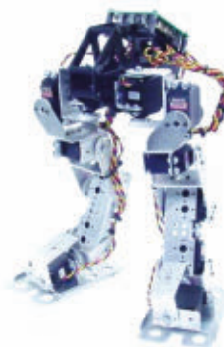
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User: Robots7



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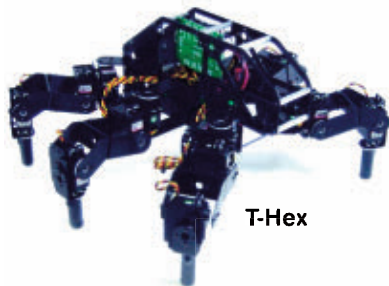
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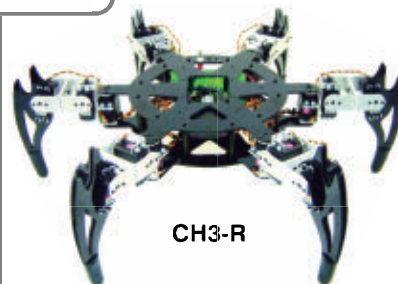
Biped 209



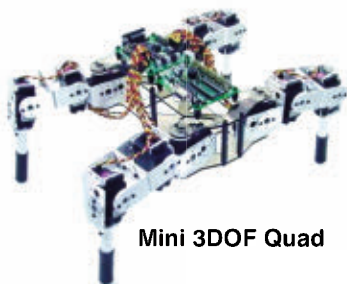
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T-Hex



CH3-R



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RobotShop Acquires Lynxmotion!

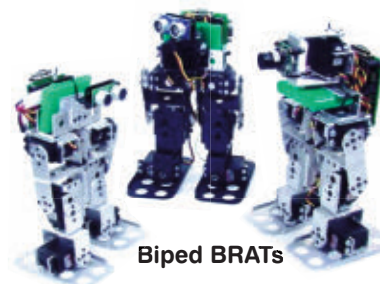
You may have already read the press release, and it's official, RobotShop has acquired Lynxmotion! It's with great honour that we'll be taking over Lynxmotion's operations and effectively continuing Lynxmotion's mission of allowing roboticists to create the robots of their dreams.

We're humbled to be able to continue Jim Frye's legacy and join this thriving community. By taking over operations, RobotShop will be able to offer Lynxmotion customers the advantages of our global logistics and infrastructure.

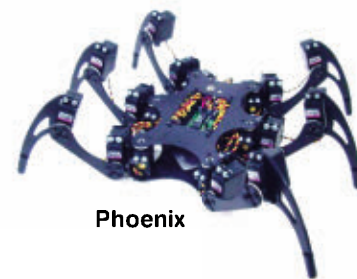
You'll be glad to know that we'll be keeping Lynxmotion's standards of producing high-quality products and kits. We plan to continue the Lynxmotion legacy.

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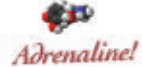
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Part 1 Using Digital Sensors With VEX

By Daniel Ramirez

Discuss this article in the *SERVO Magazine* forums at <http://forum.servomagazine.com>.

Compasses have been around for over a thousand years. Loadstone (a mineral with magnetic properties) was used to magnetize a metal pin and has been used in compasses for hundreds of years. Magnetic compasses were invented during the Chinese Han Dynasty between the second century BC and first century AD, and were used for navigation by the 11th century. The compass was introduced to medieval Europe 150 years later, where the dry compass was invented around 1300. This was supplanted in the early 20th century by liquid-filled magnetic compasses.

Figure 1 shows a modern magnetic compass used for navigation, travel, or hiking. Notice the red needle that is pointing north. By aligning the graduated ring with the red end of the needle, we can read the direction in degrees, where north is zero degrees. Unfortunately, the Earth's magnetic poles do not coincide with the rotational poles, and the positions of the magnetic poles change over time on a scale that is not extremely long by human standards. Significant movements happen in a few years. (Over millions of years, the directions of the true poles also shift because of continental drift.)

For an observer at any point on the Earth's surface, there is an angle — called the magnetic declination (or magnetic variation) — between the directions of magnetic north and true north. The magnetic declination varies at different points on the Earth, and also changes with time. Close to the equator, the magnetic declination is no more

than a few degrees, but in arctic and Antarctic latitudes, it can be much greater. Some magnetic compasses include means to compensate for the magnetic declination, so that the compass shows true directions relative to the Earth's rotational poles.

ELECTRONIC COMPASSES

An electronic compass detects the direction of the Earth's magnetic field electronically, so it can obtain a direction while it is stationary or moving. Electronic compasses are currently being used in iPhones, iPads, and Android tablets to provide the user with map directions while traveling by car or on hikes for navigational purposes. Electronic compasses are low cost and can be a very useful sensor for robotics.

Robot navigation algorithms can take advantage of an onboard electronic compass to let the robot know which direction it is heading in while running autonomously. It can also assist the operator if the robot is being maneuvered by remote control. Of course, GPS can also provide a vehicle's current heading if the robot is moving, but it is more expensive.

Thanks to technical advances in new GPS technologies, however, we now have low-cost digital electronic compasses as well, such as the one based on the Honeywell HMC6352 shown in **Figure 2**. (You can pick these up at **SparkFun.com** for around \$35 dollars.) These electronic compasses can be used

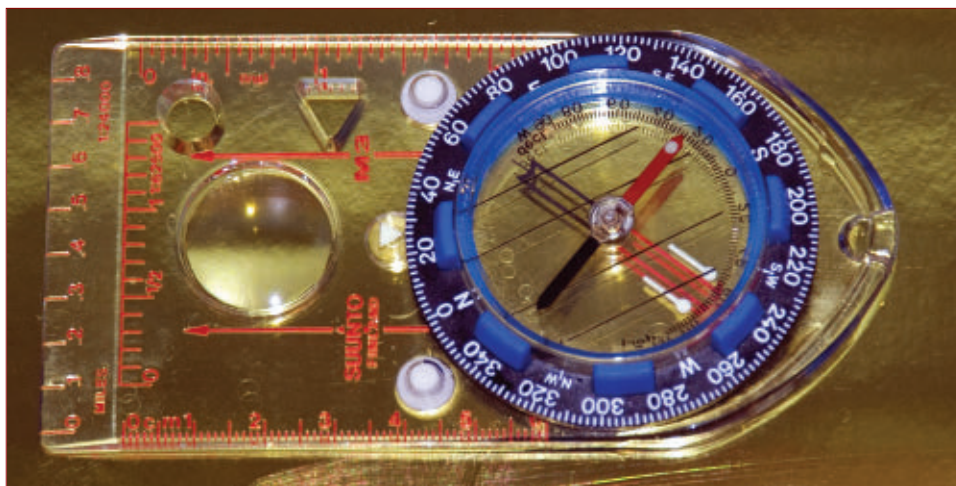


FIGURE 1. A modern magnetic compass used for navigation, travel, or hiking. Notice the red needle that is pointing north.

for VEX robotic applications as we will demonstrate in this article. The Honeywell HMC6352 electronic compass provides headings from 0° to 360° within a 1° resolution (if the compass is level). This is excellent resolution and more than adequate for most robotic applications considering the modest price of the sensor. There are some sources of interference that can reduce the theoretical resolution somewhat; these will be covered below. More expensive versions of these electronic compasses can even compensate for tilts so that they don't need to be level to give good readings.

GETTING YOUR BEARINGS STRAIGHT

Depending on where the compass is located on the surface of the Earth, the angle between true north and magnetic north can vary widely as mentioned, increasing the farther one is from the prime meridian of the Earth's magnetic field. The local magnetic declination is given on most maps to allow the map to be oriented with a compass parallel to true north. Users of such a compass have to know the local value of the magnetic declination, and adjust the compass accordingly. For this adjustment, the moving ring on the compass is used to compensate for declination from true north by adding or subtracting the declination of the user's geographic location (latitude and longitude).

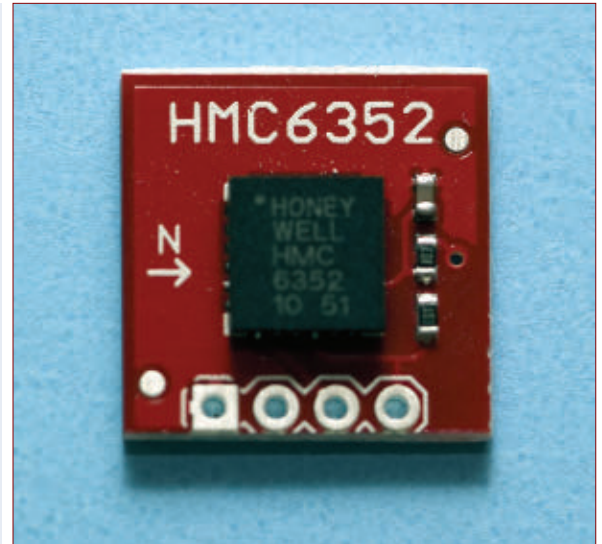
While these abnormalities (mostly caused by the Earth's molten core) can cause both magnetic and electronic compasses problems, they can be adjusted for using online declination compensation calculators provided by the National Ocean and Atmospheric Administration (NOAA)/National Geophysical Data Center (NGDC). Their online magnetic declination calculator (www.ngdc.noaa.gov/geomag/declination.shtml) allows you to enter your location (or zip code for the USA) and get the declination value. **Remember when using the declination values that east declination is positive, west is negative.**

How can we correct a compass bearing to a true bearing? We can compute the true bearing from a magnetic bearing by simply adding the magnetic declination to the magnetic bearing. This works as long as you follow the convention of degrees that west is negative (i.e., a magnetic declination of 10 degrees west is -10 and a bearing of 45 degrees west is -45). This correction is applied to both magnetic and electronic compasses, since they use the Earth's magnetic field to determine the direction where magnetic north is located.

Another cause of error in compass readings is taking them when the compass itself is not level. This source of error can be reduced by insuring that the compass is gimbaled.

Having thoroughly covered using analog sensors with

FIGURE 2. Due to technical advances in new GPS technologies, we now have low-cost digital electronic compasses such as the one shown here.



the VEX microcontroller in previous issues of *SERVO*, in this installment we will investigate new digital sensors that are starting to show up in many new consumer products including the iPhone, iPad, and automobiles (mentioned previously). We will also show you how you can take advantage of these exciting new sensors for VEX robotic applications.

First, let's cover some new sensors that are not quite available yet from Innovation First, Inc. (IFI), although the new VEX Cortex and VEX ARM9 microcontrollers do support them in hardware through their I²C interface. As of this writing, there is not yet support for them from the compiler vendors (RobotC and Easy C Pro), although I'm sure this is on their radar since these sensors are becoming very popular for robotics, consumer, and industrial applications.

JUST WHAT IS I²C?

I²C ("eye-squared cee;" Inter-Integrated Circuit; generically referred to as a "two-wire interface") is a multi-master serial single-ended computer bus invented by Philips that is used to attach low-speed peripherals to a motherboard, embedded system, cellphone, or other electronic device. From the mid 1990s, several competitors (e.g., Siemens AG, Intel Mobile Communications, NEC, Texas Instruments, STMicroelectronics, Motorola/Freescale, Intersil, Microchip, etc.) have brought I²C products to market which are fully compatible with the NXP (formerly Philips's semiconductor division) I²C system.

Figure 3 shows a typical I²C connection with one

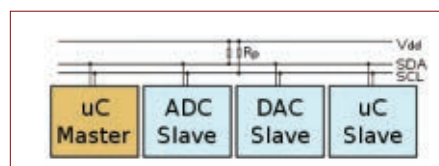


FIGURE 3. A typical I²C connection diagram using a master device with various I²C devices networked to it using the two-wire bus.

master (a microcontroller), three slave nodes (an ADC, a DAC, and a microcontroller), and pull-up resistors (R_p) uses only two bidirectional open-drain lines — Serial Data (SDA) and Serial Clock (SCL) — pulled up with resistors, with one on each signal line, ranging from 2.2K ohms to 10K ohms. These pull-ups are required for only one of the I²C devices connected to the bus. Typical voltages used are +5V or +3.3V, although systems with other voltages are permitted.

The I²C reference design has a seven-bit or a 10-bit (depending on the device used) address space. Common I²C bus speeds are the 100 Kbit/s *standard mode* and the 10 Kbit/s *low-speed mode*, but arbitrarily low clock frequencies are also allowed. Recent revisions of I²C can host more nodes and run at faster speeds (400 kbit/s *fast mode*; 1 Mbit/s *fast mode plus* or Fm+; and 3.4 Mbit/s *high-speed mode*). These speeds are more widely used with embedded systems rather than on PCs. There are also other features, such as 16-bit addressing.

Note that the bit rates quoted are for transactions between the master and slave without clock stretching or other hardware overhead. Protocol overheads include a slave address and perhaps a register address within the slave device, as well as per-byte ACK/NACK bits. So, the actual transfer rate of user data is lower than those peak bit rates alone would imply. For example, if each interaction with a slave inefficiently allows only one byte of data to be transferred, the data rate will be less than half the peak bit rate. The maximum number of nodes is limited by the address space, and also by the total bus capacitance of 400 pF which restricts practical communication distances to a few yards.

There is an I²C bus master and the I²C peripherals which respond to commands sent by the master controller. Each device on the bus listens for its address, and wakes up when the address sent by the master matches the selected peripheral address. Using the I²C bus, we can network up to 128 devices using seven-bit addressing, and up to 16,384

devices using 14-bit addressing. Bus capacitance will limit the distance at which we can reliably communicate, and will probably also limit the actual number of devices to well below the theoretical limits.

The master initiates the I²C message transfers using its Start condition. Each device on the I²C bus listens for its address before responding. The I²C interface is known as a synchronous serial interface since one of the signals is a clock signal, unlike serial RS-232 which is asynchronous. It is similar to the SPI four-wire interface.

The I²C message strings are just sequences of I²C conditions sent from the master to the peripherals. These include the Start condition, Re-start condition, Acknowledge condition, Not Acknowledge condition, and the Stop condition. We will describe these sequences in greater detail in Part 2 when we cover the necessary I²C firmware.

HOW I²C CAN BE USED ON VEX

You may be asking yourself how I²C relates to VEX robotics. Well, see for yourself in **Figure 4**, which shows the new VEX Cortex microcontroller and a new 393 motor with the integrated quadrature encoder connected to the I²C port. This is the first I²C sensor product to be released by IFI. The new VEX Pro microcontroller based on an ARM9 core also has a similar I²C port. Why would you want to use the I²C interface?

The main reason for VEX users is the variety of new digital sensors and actuators that can be connected to the I²C bus. These can easily be interfaced. Other advantages are that digital sensors are much simpler to use. In addition to providing digital readings, they don't require much calibration since they are usually factory calibrated.

Another advantage is that they can easily be networked to processors with a limited number of general-purpose I/O pins. Commercial applications for digital sensors are growing each day. In response to this demand, new digital sensors are appearing on the market; they are being used for electronic applications that require sensors such as home heating, HVAC, temperature, humidity, pressure, weather applications, automobile, commercial appliances, etc. Let's start playing with these new digital sensors that should be available soon for the VEX microcontroller.

The new VEX Cortex microcontroller allows users to connect advanced digital sensors to it using its built-in I²C hardware interface. Just think of all the sensors and other devices that we will be able to use for our VEX robot applications! These include electronic compasses, GPS, serial EEPROMs, digital temperature sensors, pressure, humidity, XYZ accelerometers, six to nine DOF gyros, DC motor controllers, servo controllers, stepper motor controllers, LCD displays, and math co-processors.

Another advantage for using I²C is saving precious GPIO pins on the VEX microcontroller. It

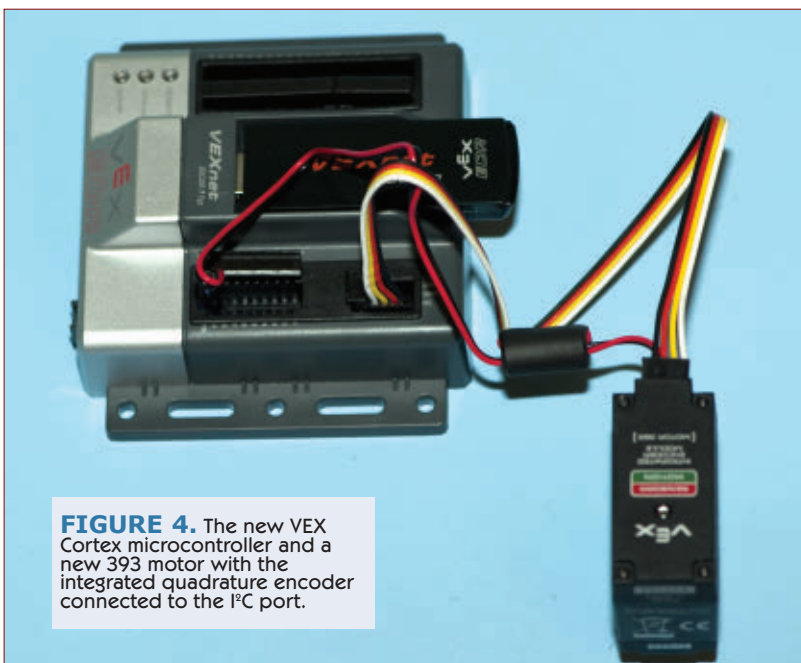


FIGURE 4. The new VEX Cortex microcontroller and a new 393 motor with the integrated quadrature encoder connected to the I²C port.

only requires two GPIO pins (not including power and ground): one for the SCL signal and one for the SDA signal. From this two-wire bus, we can connect as many sensors as we want, up to the addressing limits mentioned previously.

This new VEX Cortex feature seems to leave all the VEX 0.5 microcontroller users out in the cold, unfortunately, since it does not provide a dedicated I²C port. Still, we can do something about this state of affairs in that we can simulate this interface on the original VEX v0.5 microcontroller using a technique known as bit banging (this will be demonstrated in Part 2). When using bit banging on the VEX 0.5 microcontroller, the data rates will be considerably slower than those referred to above, but we should still be able to read most of the devices with no problems.

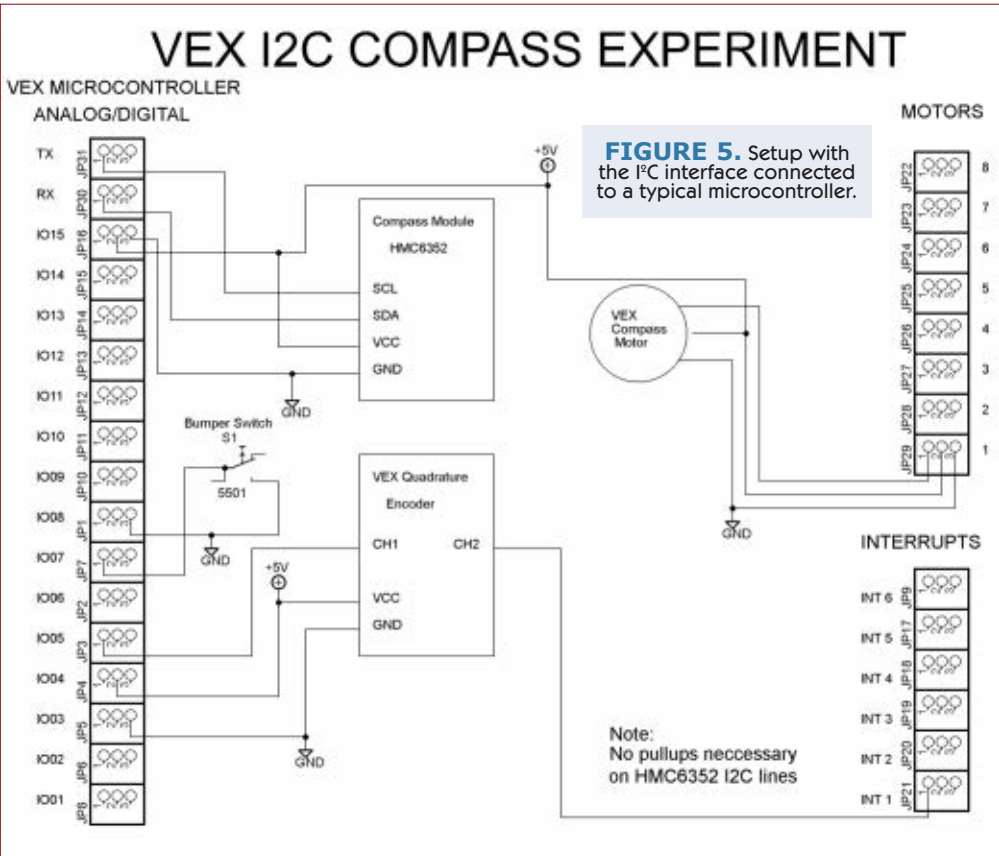
In fact, the EasyC firmware provided for the VEX 0.5 microcontroller can easily be adapted to run on the VEX Cortex and the VEX Pro (ARM9) microcontrollers using their I²C bus. This means some minor changes to the application are required to use direct EasyC I²C instructions supported by those controllers instead of the bit banded instructions. In fact, only the main routine controlling the compass would need to be converted.

We mentioned that an electronic compass such as the HMC6352 module can be interfaced to the VEX microcontroller (what better way to get your robot to travel in a specific direction than by using an electronic compass). Using it, we can tell our robot to simply move north 20 inches from its current position, then move east 20 inches, then move south 20 inches, then move west 20 inches, and then move north another 20 inches back to its original position. It will have traveled in a square trajectory path.

What does all this information mean for VEX users? The I²C port on the Cortex microcontroller opens a whole array of new sensors from both IFI and third-party vendors. These are sensors that require little or no calibration. They can also be auto-configured for your VEX robotics application using the device ID and device configuration information stored in the sensor's local non-volatile memory (usually EEPROM). Just think of how many sensors you can use on your robot using only one I²C port.

THE GREAT COMPASS EXPERIMENT

In this experiment, we will show you how to make your



own electro-magnetic compass using some VEX components and an I²C based electronic compass to interface to the HMC6352 electronic compass. The connection to the compass module using a VEX v0.5 microcontroller is shown in **Figure 5**.

The bill of materials used in this experiment is shown in **Table 1**. Be sure to connect the ground wire and power to

TABLE 1. Bill of materials for the VEX electromechanical compass.

QTY	DESCRIPTION	SOURCE
1	VEX microcontroller	Innovation First, Inc. (IFI) www.vexforum.com
1	7.2 volt battery	IFI
1	Wire-wrap cable	RadioShack www.radioshack.com
1	VEX bumper switch	IFI
1	HMC6352 electronic compass	SparkFun www.sparkfun.com
1	12-tooth gears: 0.5" (12.7 mm) pitch dia.	IFI
1	36-tooth gears: 1.5" (38.1 mm) pitch dia.	IFI
1	60-tooth gears: 2.5" (63.5 mm) pitch dia.	IFI
1	84-tooth gears: 3.5" (88.9 mm) pitch dia.	IFI
1	VEX quadrature encoder	IFI
4	Square metal shafts	IFI
1	VEX three-wire motor	IFI

the electronic compass module or it will not function.

Although IFI currently does not support the I²C interface on this microcontroller, we can simulate the interface using bit banging that generates the required I²C conditions (waveforms) by using the EasyC Pro firmware which will be provided in Part 2. Using this method is not as fast or as efficient as the hardware version, but it is fast enough for our purposes. We will use EasyC professional for this experiment.

In addition, you should be able to reproduce this experiment using the VEX Cortex and even the VEX Pro (ARM9) microcontrollers by just plugging the hardware directly into the I²C port provided on them. In this case, the bit banging firmware would be omitted but the compass application would still be used.

Follow the schematic when making all the electrical connections. On the VEX 0.5 microcontroller, we will use the serial TX pin on the digital I/O block for the I²C SCL line, and use the serial RX pin for the I²C SDA line. Note that there are no customary pull-ups to the SCL and SDA lines shown in the schematic. This is because the SparkFun module already has them included in it.

The schematic also provides guidance for connecting the two- or three-wire VEX motor, and the VEX quadrature encoder and a bumper switch used for calibration of the compass.

ASSEMBLING THE ELECTROMECHANICAL (EM) COMPASS

Use the VEX gears, axles, and metal parts, along with the VEX motor and optional quadrature optical encoder, to build the mechanical portions of the EM compass. Use

Figure 6 as a guide for mounting the parts necessary for the compass gear train assembly, and for mounting the VEX motor and quadrature optical encoder.

The mechanical assembly was kept as simple as possible. The gears used can be found at the IFI website. As you can see from the **figure**, one each of the following gears was used. They are 12-tooth, 36-tooth, 60-tooth, and 84-tooth gears, which were necessary for the gear reduction needed for the EM compass.

The pointer can be made from metal parts or it can even be cut out of wood (non-metallic) to lessen the magnetic interference. If metal parts are used for the north pointer, then use a wooden stick or plastic rod on the south end to mount the compass module as far from the metal parts as possible.

The completed DIY electromechanical compass made with metal parts is shown in **Figure 7**. To operate it, you will need to first program it using the 0.5 microcontroller; download and run the firmware provided using the IFI bootloader or the Easy C Pro bootloader. The pointer mechanism and the quadrature optical encoder (if used as a reference scale) will both need to be calibrated to zero degrees (north). Both the firmware and calibration process will be covered in Part 2.

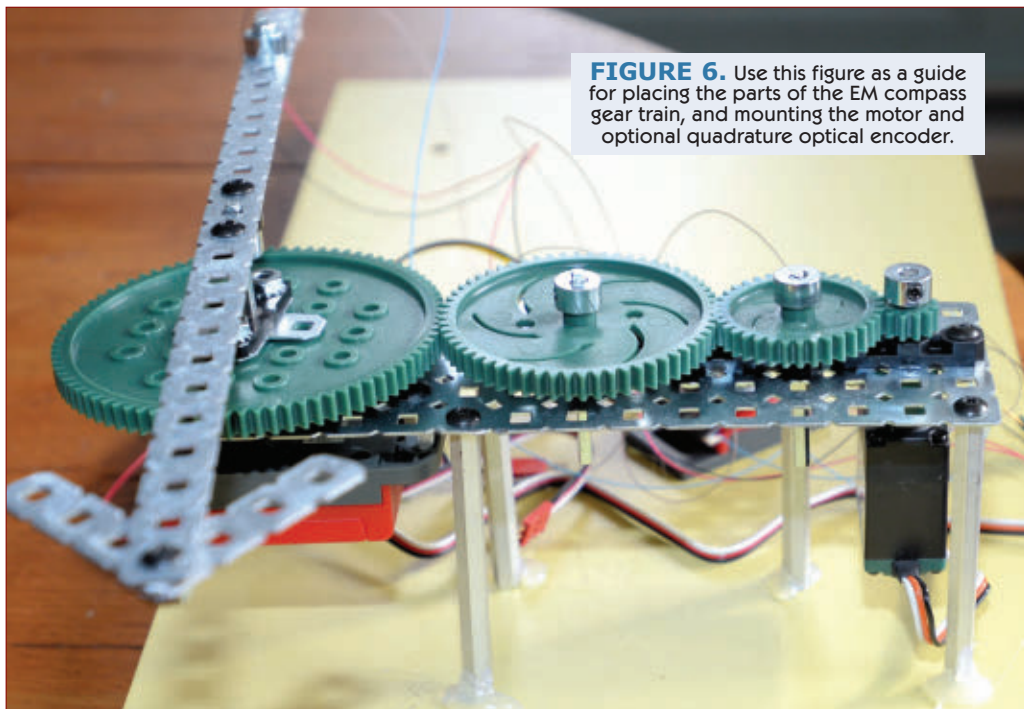
STEAMPUNK THE EM COMPASS

If you want to “steampunk” the project to make it look cool, you can use a compass cardinal rose pattern such as the one in **Figure 8** to make a really large compass that will impress your friends and neighbors. Other compass rose patterns are available on Wikipedia at http://en.wikipedia.org/wiki/Compass_rose. It may require trips to your local arts and crafts supply store, hardware store, and office supply store. A file with the rose is provided at the article link.

If you would like to customize the pattern, use a photo editor to change the colors or to tweak it the way you want. To make it more durable, have the pattern laminated. You will also need to reinforce the compass pattern with a large circular disk cut from stiff cardboard to form the base of the compass so that you can glue the pattern to it. Then, drill a small hole in the center of the disk and allow the output axle from the largest gear to go through.

Attach the pointer to it just like any classic magnetic compass, then finally place a large band (made from gold

FIGURE 6. Use this figure as a guide for placing the parts of the EM compass gear train, and mounting the motor and optional quadrature optical encoder.



or aluminum foil and cardboard strip) around the circumference of the laminated compass base.

For operational safety and further weatherproofing, it may also be wise to carefully cover the top of the compass with a large clear circular plastic or glass lid to keep hands from getting near the compass pointer. The compass should be mechanically operational at this point.

Warning: Wear goggles when operating this compass, especially if it is not covered with a clear plastic or glass lid. Keep the area where it is being used clear of any extraneous objects and keep clear of the rotating compass pointer, especially when powering the microcontroller or programming it since it may move inadvertently.

SUMMING IT UP

We covered digital sensors using the I²C bus and how they are used for robotics applications. In the process, we learned a bit about reading both magnetic and electronic compasses. We also found out that they can be used for many other electronic applications that require legacy analog sensors, such as home heating, HVAC, humidity, weather applications, etc. The nice thing about using digital sensors is that they are usually factory calibrated so that the readings make sense when they're first turned on.

In addition, we learned what the I²C bus was and how I²C sensors can be networked together using this bus, as long as one of the devices uses pull-up resistors on the two signal lines (SCL or SDA). We also discovered that the I²C protocol is composed from simple I²C conditions such as START, STOP, ACK, and NACK.

As discussed, there are many other kinds of I²C devices that can be used for VEX applications, including: electronic compasses, gyros, XYZ accelerometers, serial EEPROMs, I²C LCD displays, DC motor controllers, stepper motor controllers, math co-processors, etc.

We also discovered (to our dismay) that magnetic north and true north do not necessarily coincide, and that we have to compensate for this fact by adding or subtracting the declination from true north based on our current latitude.

Recall, we observed from the experiment that the compass has to be kept relatively level to obtain accurate readings. This is why more modern electronic compasses are mounted on gimbals and are floated in clear water. More expensive electronic compasses have this feature built in to compensate for tilt.

A challenge to the reader is to use the information

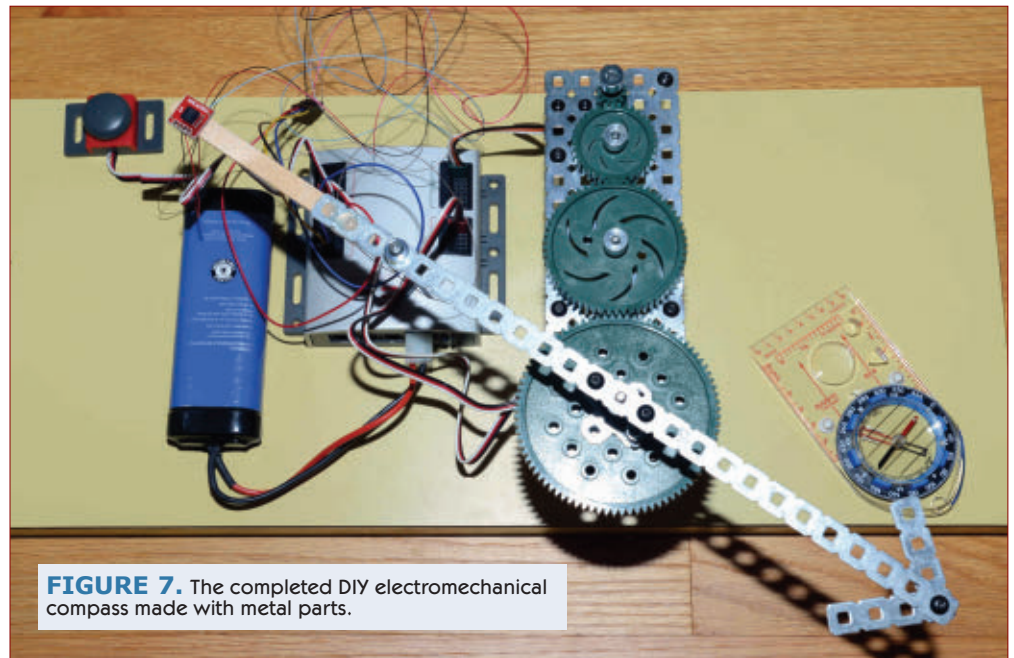


FIGURE 7. The completed DIY electromechanical compass made with metal parts.

contained in this article to make a self-leveling electronic compass.

Have the Steampunk EM compass ready for the next installment because we will provide the details of the I²C drivers written in EasyC Pro and the calibration process necessary for the EM compass to function correctly.

We will also cover other kinds of digital I²C sensors that can be interfaced to microcontrollers using the I²C drivers. Until VEX time!!! **SV**

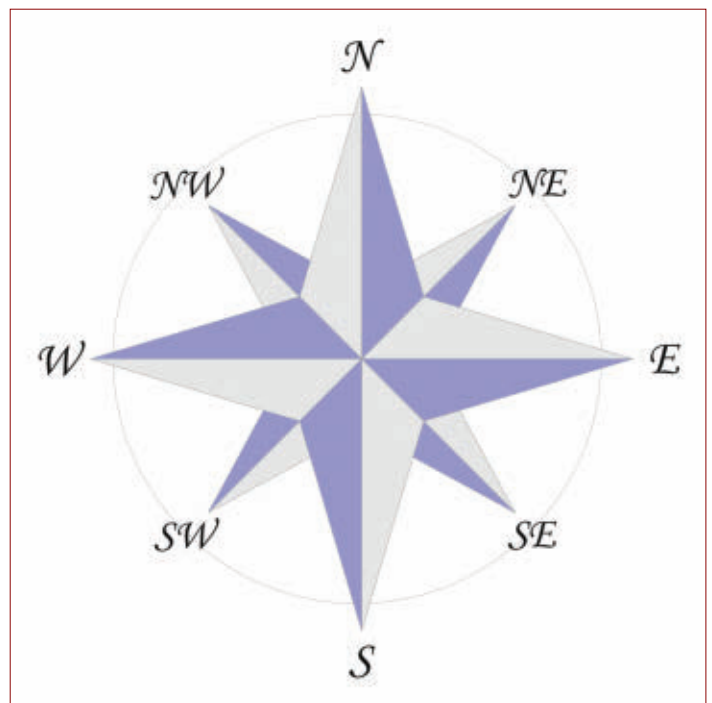


FIGURE 8. If you want to "Steampunk" the project to make it look cool, you can use a compass cardinal rose pattern such as the one shown here to make a really large compass that will impress your friends and neighbors.

Build the Kronos Flyer

Part 3: Assembly



by Michael Simpson

www.servomagazine.com/index.php?/magazine/article/january2013_Simpson

Discuss this article in the SERVO Magazine forums at <http://forum.servomagazine.com>

Before getting started, let me give you an overview of the assembly process of our Kronos flyer. You are going to sandwich four booms with two platform sections. You will then attach your power distribution board and landing gear. The power distribution board and landing gear also serve as an anchor for the booms.

Next, you will install the motors and electronic speed controls, then finally, the component platform will be added. It is best to preassemble the Flyer without using any kind of thread lock. Later, you can go back and add a drop to the end of the screws. If you use green thread lock, you can place the

drop directly over the attached screw; it will soak into the threads. Use only the smallest amount. If you use the blue thread lock, you will need to remove the nut and add a drop to the threads at the end of the screw. On screws that have multiple nuts, you only need to add thread lock to the last nut. Adding thread lock to the other nuts may make disassembly difficult if you need to do repairs.

Note that as an option, I have had good success with using small #6 lock washers instead of thread lock. I like to tinker with my machines, so using thread lock becomes somewhat problematic.

Prerequisites

Platform and Booms

Before starting the actual frame assembly, you need to cut out your platform parts. You will also need to drill holes in your booms and platforms. In the last article, I listed the parts and sizes for the booms. I also listed the sizes for the platform pieces. However, in order to make the platform fit on a single 12" x 12" sheet of hobby ply, I changed the overall size of the platform. The platform pieces are now 5-3/8" x 5-3/8". This will also allow you to use an inexpensive coping saw to cut the parts out.

On the Kronos Robotics website, there is a PDF file that contains the printable templates used to cut out and drill these parts. You can download the templates and instructions for cutting the parts at www.kronosrobotics.com/multirotor/kronosflyer/assembly.

If you want to paint the parts, this is the time to do it. I have found that acrylic paint works very well. If you paint it with black acrylic paint, you can get by with one or two coats. Any other color will most likely require multiple coats. Sand lightly with a fine sanding sponge between coats for a smooth plastic-like finish. The platform parts and booms should be completed before proceeding.

Motors

I have added an additional motor to the bill of materials listed on the Kronos Robotics website. Whichever

motors you choose, they need to be assembled. All the motors listed are assembled in the same manner and should resemble those shown in **Figure 1**.

The motor mount is attached to the bottom of the motor (the end with the shaft). The prop adapter is attached to the opposite end. Be sure to use some green or blue thread lock on each screw. Just a tiny drop will keep the parts from vibrating loose.

ESCs

In the bill of materials, I list several choices for ESCs (Electronic Speed Controller). Of all the ESCs listed, they can be broken down into two types: Turnigy Plush and Turnigy MultiStar. If you are using the MultiStar ESCs, you can skip this section, since they come with connectors pre-installed. If you are using the Plush series, you need to attach 3.5 bullet connectors to the ESC leads. Female bullets connect to the three motor ends of the ESC leads. Male bullet connectors are connected to the two battery ends of the ESC, as shown in **Figure 2**.

Be sure to cover the connectors with heat shrink to keep the leads from shorting. This means covering the full length of the female



FIGURE 1.

connectors, and about half of the male ends as shown in **Figure 2**. The exposed portion on the male connector will be inserted into the power distribution board.

Propellers

You need to properly balance your props before installation on your quad. This is done with a prop balancer. There are plenty of examples on how to do this on the web.

Frame Assembly

Before starting the assembly, gather all your parts together like the ones shown in **Figure 3**.

Again, if you are going to paint the wood parts, you should do it before assembly because you won't be able to once it's assembled. I am not painting the one shown here so it makes it easier to see the details in the photos.



FIGURE 2.

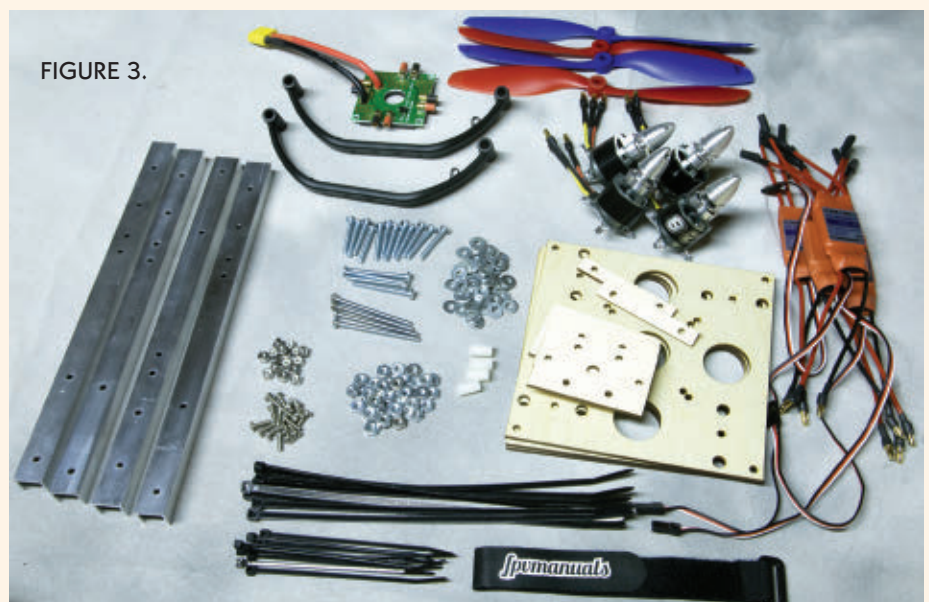


FIGURE 3.

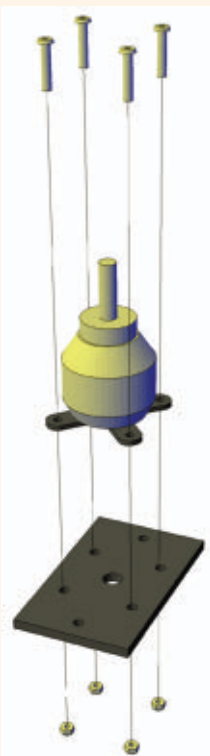


FIGURE 4.

Assembly

Okay, all the parts are on hand. Let's get started.

Step 1

Using four #4-40 x 1/2" or #4-40 x 3/8" machine screws, attach the motor to the motor platforms as shown in **Figure 4**. Use four #4-40 lock nuts to secure. Note that I don't show any #4 washers. If you want, you can add them to the screws on the underside of the platform. I have found that the locknuts work fine without them. Once complete, set aside.

Step 2

Using four #6-32 x 1" machine screws and washers, attach the boom to the platform using the holes shown in **Figure 5**. Notice the orientation of the holes on the top and the bottom platforms. They must be the same.

Also, the slot in the booms is

facing up. Secure with a washer and #6-32 hex nut. Finger tighten only, as you will be coming back and adding thread lock to the nuts later.

Step 3

Using four #6-32 x 2" machine screws and washers, insert the screws into the holes on the bottom of the platform shown in **Figure 6**. Secure with a #6 washer, 1/2" nylon spacer, and hex nut. Finger tighten.

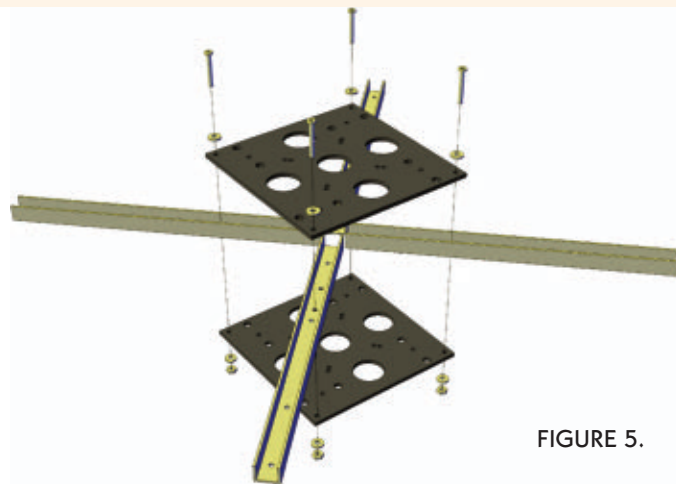


FIGURE 5.

FIGURE 8.

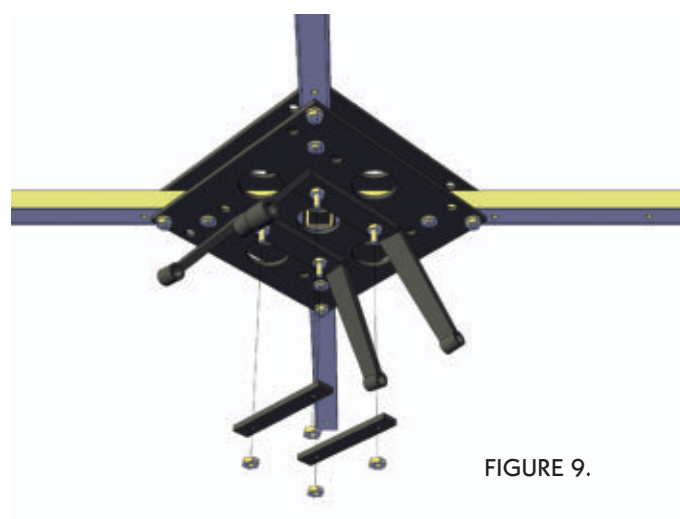
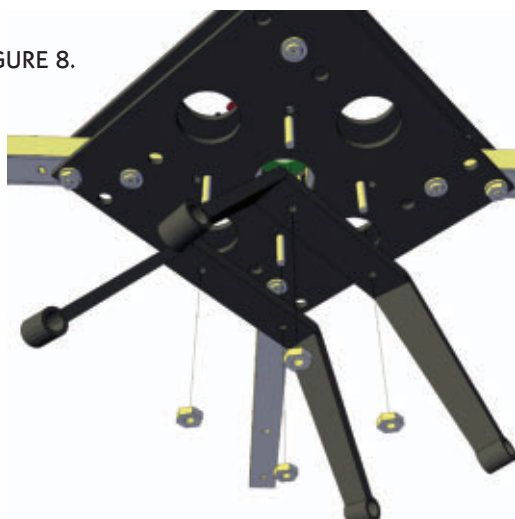


FIGURE 9.

Step 5

Use a 1/8" drill bit and enlarge the two holes on each of the landing gear pieces. Next, place the holes in one set of the landing gear legs, up against the two front screws protruding from the bottom of the platform. Use a screwdriver to twist the screws until you pull the landing gear up tight against the lower platform. The landing gear legs are slightly splayed; you want the legs toward the front of the craft when the base of the legs is up against the platform. Repeat the process with the

two rear screws and the other set of legs. This set should be splayed towards the rear of the craft.

Secure the legs with a #6-32 hex nut in each of the exposed screws as shown in **Figure 8**. Tighten with a wrench. We won't be adding thread lock to this set of nuts.

Step 6

Take the two landing gear braces and slip them over the exposed screws as shown in **Figure 9**. Secure with four hex nuts. You want to add a drop of blue or green thread lock to each

of the nuts and tighten with a wrench. Don't over-tighten or you will damage the braces.

Step 7

Add thread lock to each of the four bottom nuts located at the four corners of the platform. If you are using green thread lock, you can add the drops to the top of the loose nuts and then tighten. If you are using blue thread lock, you will need to remove the nut and add a drop to the tip of each machine screw. Tighten the nuts with a wrench. Don't over-tighten

Step 4

Using a 9/64" drill bit, widen the four mounting holes in the power distribution board. Remove the rubber backing from it.

Using four #6-32 x 1.5" machine screws, attach the power distribution

board to the platforms as shown in **Figure 7**. Notice there is a set of #6 washers between the power board and the upper platform.

Make sure you use the four inner holes in the upper platform. Also, it is likely that the fit is going to be tight. You will probably have to use a

screwdriver to position the screws all the way through the platforms and boom. If the screw binds, back it out and make sure it is lined up with the hole in the boom and the lower platform. Note that the battery connector represents the back of your craft. The opposite end is the front.

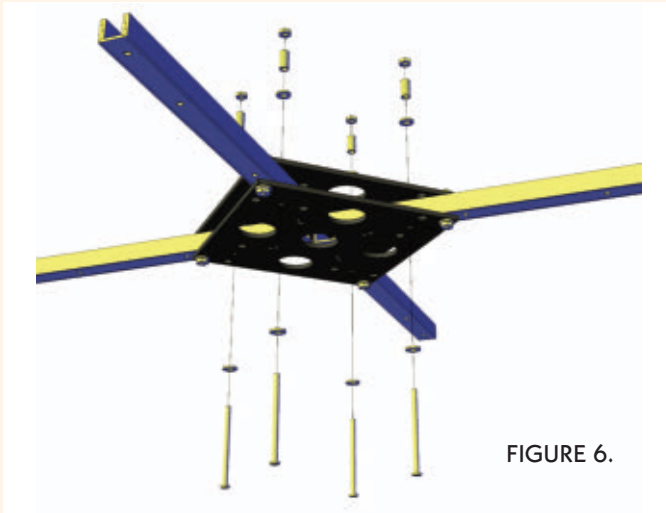


FIGURE 6.

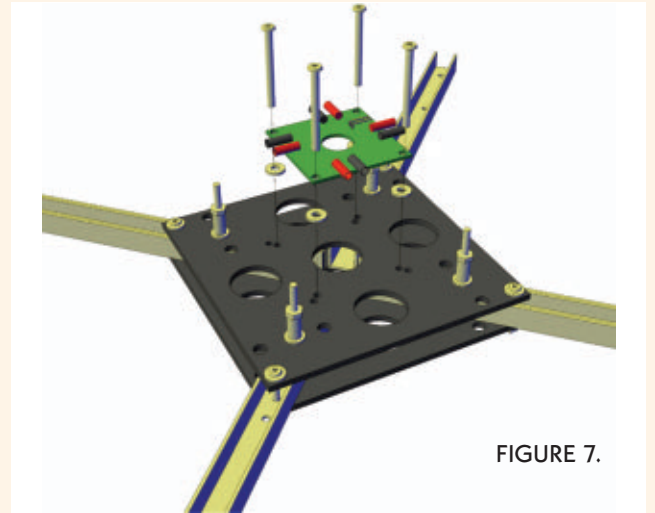
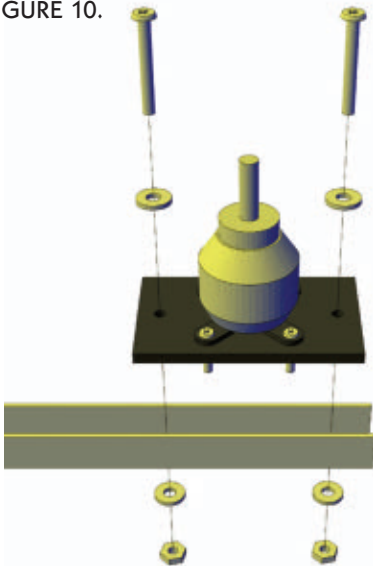


FIGURE 7.

FIGURE 10.



these nuts, as you make break the corners off the platform.

Warning!!! Don't use red thread lock or you won't be able to remove the nuts later!

Step 8

Using two #6-32 x 1" machine screws and washers, attach a motor assembly to the end of each boom as shown in **Figure 10**. Secure with a washer and #6-32 hex nut. Add a drop of thread lock to each nut and tighten with a wrench. Be sure the wires are facing the center of the craft.

Step 9

Use two eight inch tie wraps to

mount the ESC to the platform as shown in **Figure 11**. Use the two 1/4" holes in the platform to thread the tie wraps. The two battery leads should be plugged into the power distribution board. Plug the red lead into the red plug. Plug the black lead into the black plug. Leave the three motor leads unconnected at this time.

If you are using NTM motors and Multistar ESCs, you can optionally install the ESC between the two platforms as shown in **Figure 12**.

This is possible because the NTM motor leads and the Multistar leads are longer than their counterparts. With Plush ESCs, the leads are too short as are the leads on the SK3 motors.

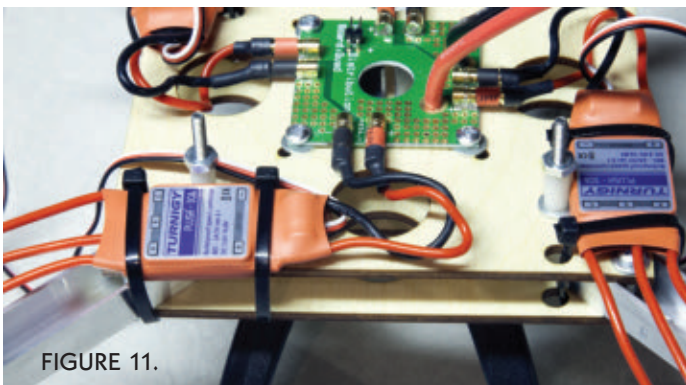


FIGURE 11.

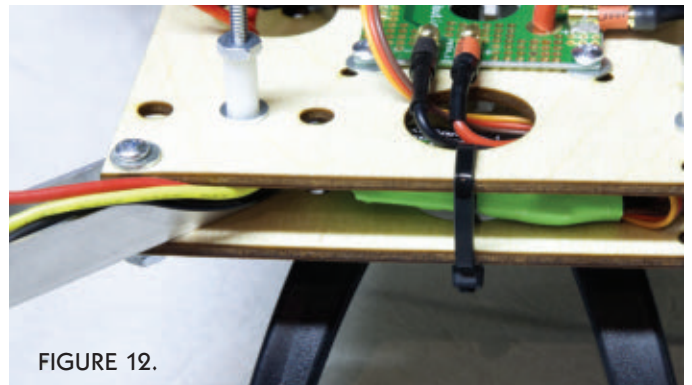


FIGURE 12.

Step 10

Attach four #6-32 x 5/8" machine screws with washers to the underside of the components platform as shown in **Figure 13**.

Secure with washers and #6-32

hex nuts. Add a drop of thread lock and tighten these nuts. Note that the outer four holes near the center of the platform are used. These screws will be used next month to secure your controller mount.

Step 11

Slip the component platform over the four machine screws shown in **Figure 14**. Secure with washers and #6-32 hex nuts. Finger tighten only. You'll be removing this platform later.

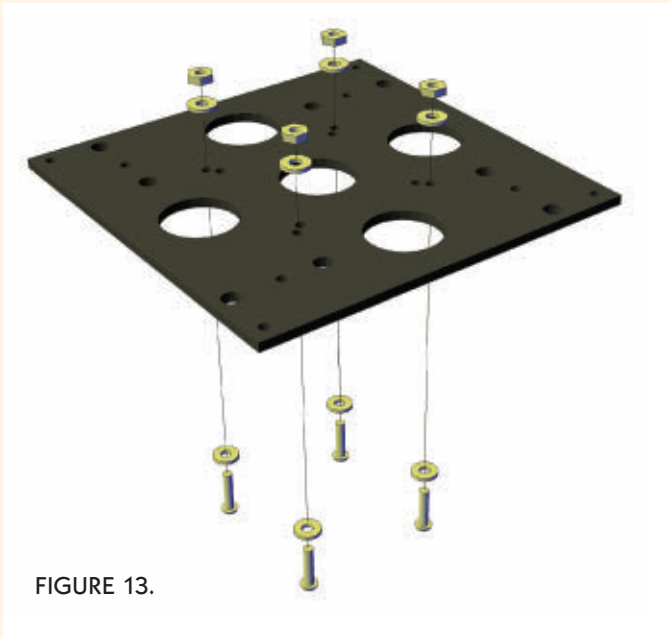


FIGURE 13.

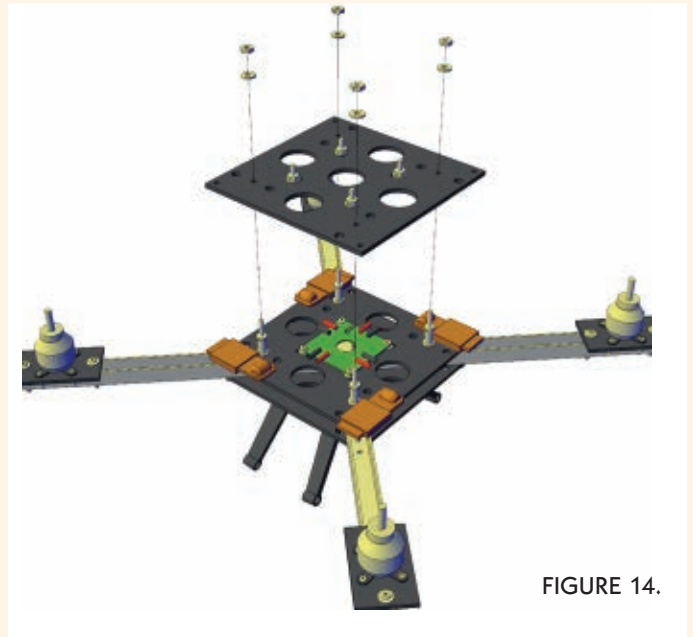


FIGURE 14.

Conclusion

Your frame is now complete; see **Figure 15**.

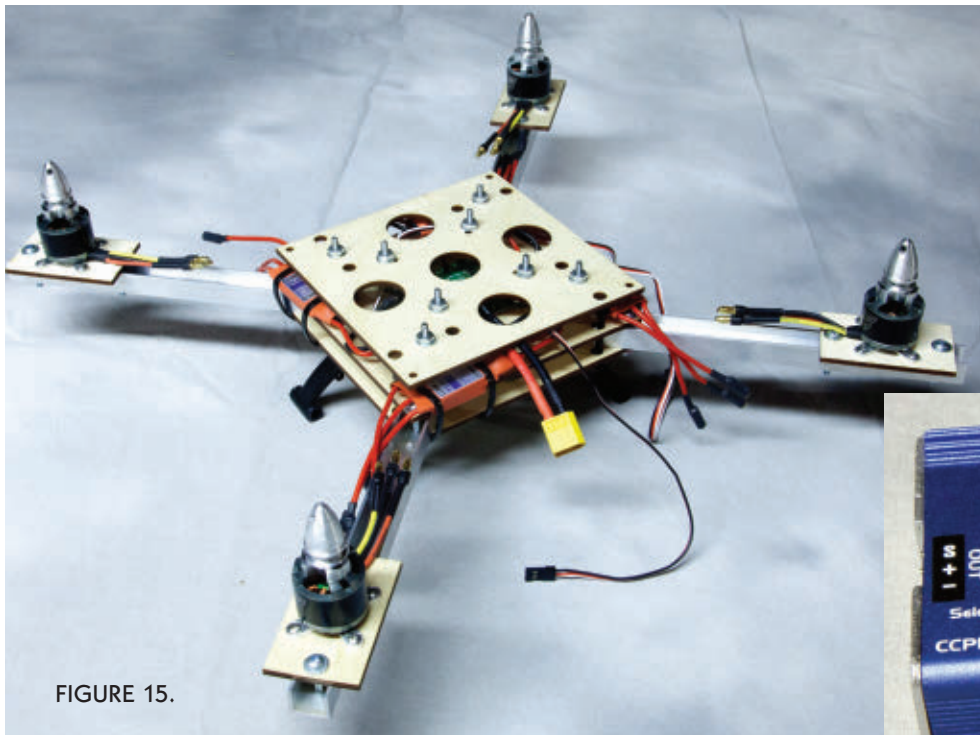


FIGURE 15.

Next month, we will connect the motors and set their direction. We will program the ESCs and install a NAZA flight controller. Once the ESCs are properly set up, we will install the props. Here are some things you will need to have on hand next month:

Servo Tester

In order to test the direction of the motors and program the throttle range, you will need a servo tester like the one shown in **Figure 16**.



FIGURE 16.

This particular servo tester works very well.

- Turnigy Servo Tester:
HK# TGY-ST

This is available at the Hobby King international warehouse.

ESC Programming Card

When you ordered your ESCs, you should have ordered the proper programming card for them. If not, you need to order one now. These are very popular and HobbyKing is frequently out of stock.

The card shown in **Figure 17** is used to program the Plush ESCs; the card shown in **Figure 18** is used to program the Multistar ESCs.

Note that you can program the ESCs manually using your transmitter; however, it's not easy and I won't be covering manual programming in these articles. Some functionality may not be available when programming manually.

- Turnigy Plush Programmer: HK# TR_PC
- Turnigy Multistar Programmer: HK# 9351000006

These are available at the Hobby King international warehouse.

NAZA Flight Controller

Next month, I will be covering the installation of the NAZA flight controller. The NAZA flight controller has an optional GPS unit available. I will talk a little about this upgrade in the final article in this series.

You can mount the NAZA directly to the component platform of the Kronos Flyer. However, if you decide that you want to build other craft, you may want to move your NAZA from craft to craft.

To make this easy, I have come up with what I call the "Universal NAZA Mount" shown in **Figure 19**. The UNM is a set of mini platforms that hold the NAZA, VU, GPS, and your radio receiver. By having all these items mounted in one place, it makes it very easy to move the NAZA from



FIGURE 17.



FIGURE 18.

craft to craft. Additional information on the UNM can be found at www.kronosrobotics.com/multirotor/unm.

Radio and Batteries

You will need to have your radio, battery, and charger on hand. These were discussed last month.

Final Thoughts

If you have any questions about the parts required to build the Kronos Flyer, please visit the Kronos website for additional information and updates to the bill of materials. **SV**

Feel free to ask me questions directly on the *SERVO Magazine* forums at forum.nutsvolts.com/viewtopic.php?f=49&t=16866.

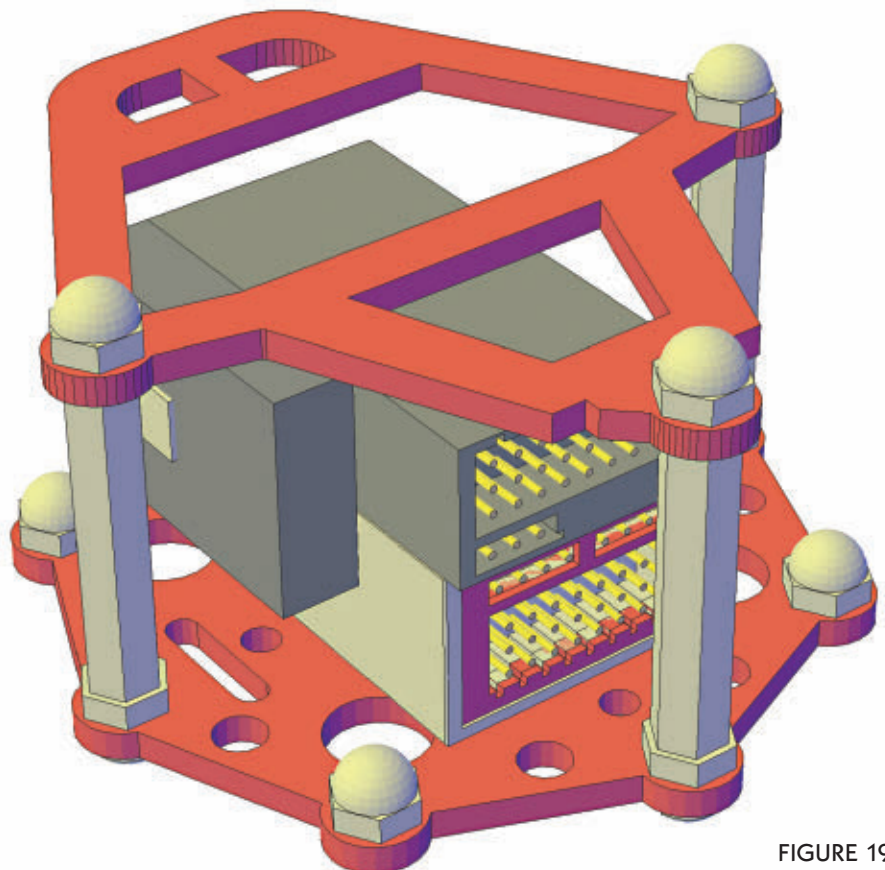


FIGURE 19.

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ROBOTICS

Robot Builder's Bonanza, Fourth Edition by Gordon McComb

Robot Builder's Bonanza, Fourth Edition includes step-by-step plans for a number of motorized platforms. The book is described as a compendium of robotics topics, containing more than 100 projects, including 10 robot designs new to the fourth edition. These modular robots are low cost, and are made to be reproduced by readers with no training in mechanical construction.



\$29.95*

Mechanisms and Mechanical Devices Sourcebook 5th Edition

by Neil Sclater

Fully revised throughout, this abundantly illustrated reference describes proven mechanisms and mechanical devices. Each illustration represents a design concept that can easily be recycled for use in new or modified mechanical, electromechanical, or mechatronic products. Tutorials on the basics of mechanisms and motion control systems introduce you to those subjects or act as a refresher.



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Making Things Move: DIY Mechanisms for Inventors, Hobbyists, and Artists by Dustyn Roberts

In *Making Things Move: DIY Mechanisms for Inventors, Hobbyists, and Artists*, you'll learn how to successfully build moving mechanisms through non-technical explanations, examples, and do-it-yourself projects — from kinetic art installations to creative toys to energy-harvesting devices. Photographs, illustrations, screenshots, and images of 3D models are included for each project.



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Build Your Own Humanoid Robots

by Karl Williams

GREAT 'DROIDS, INDEED!

This unique guide to sophisticated robotics projects brings humanoid robot construction home to the hobbyist. Written by a well-known figure in the robotics community, *Build Your Own Humanoid Robots* provides step-by-step directions for six exciting projects, each costing less than \$300. Together, they form the essential ingredients for making your own humanoid robot.

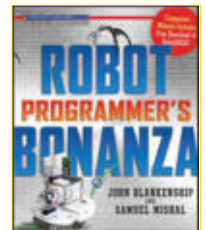


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Robot Programmer's Bonanza by John Blankenship, Samuel Mishal

The first hands-on programming guide for today's robot hobbyist!

Get ready to reach into your programming toolbox and control a robot like never before! *Robot Programmer's Bonanza* is the one-stop guide for everyone from robot novices to advanced hobbyists who are ready to go beyond just building robots and start programming them to perform useful tasks.

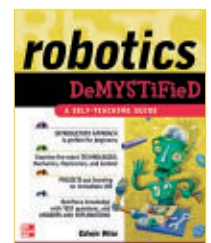


\$29.95

Robotics Demystified

by Edwin Wise

YOU DON'T NEED ARTIFICIAL INTELLIGENCE TO LEARN ROBOTICS! Now anyone with an interest in robotics can gain a deeper understanding — without formal training, unlimited time, or a genius IQ. In *Robotics Demystified*, expert robot builder and author Edwin Wise provides an effective and totally painless way to learn about the technologies used to build robots!



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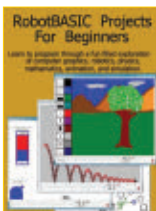
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RobotBASIC Projects For Beginners

by John Blankenship,
Samuel Mishal

If you want to learn how to program, this is the book for you. Most texts on programming offer dry, boring examples that are difficult to follow. In this book, a wide variety of interesting and relevant subjects are explored using a problem-solving methodology that develops logical thinking skills while making learning fun. RobotBASIC is an easy-to-use computer language available for any Windows-based PC and is used throughout the text.

Price \$14.95

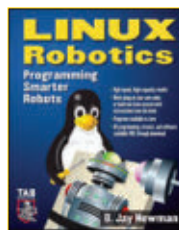


Linux Robotics

by D. Jay Newman

If you want your robot to have more brains than microcontrollers can deliver — if you want a truly intelligent, high-capability robot — everything you need is right here. *Linux Robotics* gives you step-by-step directions for "Zeppo," a super-smart, single-board-powered robot that can be built by any hobbyist. You also get complete instructions for incorporating Linux single boards into your own unique robotic designs. No programming experience is required. This book includes access to all the downloadable programs you need.

\$38.95



CNC Machining Handbook: Building, Programming, and Implementation

by Alan Overby

The *CNC Machining Handbook* describes the steps involved in building a CNC machine and successfully implementing it in a real world application. Helpful photos and illustrations are featured throughout. Whether you're a student, hobbyist, or business owner looking to move from a manual manufacturing process to the accuracy and repeatability of what CNC has to offer, you'll benefit from the in-depth information in this comprehensive resource.

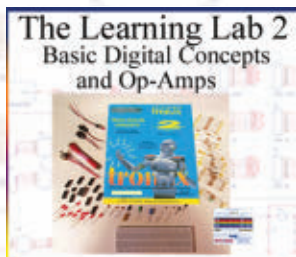
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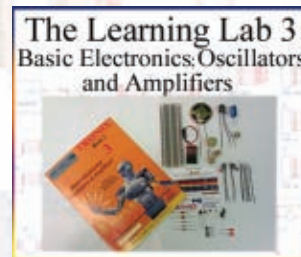
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The labs in this series — from GSS Tech Ed — show simple and interesting experiments and lessons, all done on a solderless circuit board. As you do each experiment, you learn how basic components work in a circuit, and continue to build your arsenal of knowledge with each successive experiment.

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SPECIAL OFFERS

16-Bit Complete Combo



Forbidden LEGO

by Ulrik Pilegaard / Mike Dooley
Forbidden LEGO introduces you to the type of free-style building that LEGO's master builders do for fun in the back room. Using LEGO bricks in combination with common household materials (from rubber bands and glue to plastic spoons and ping-pong balls) along with some very unorthodox building techniques, you'll learn to create working models that LEGO would never endorse.



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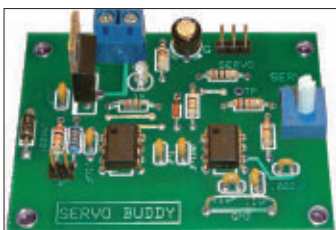


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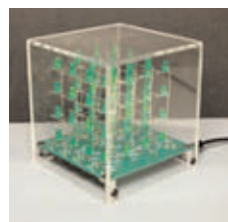
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3D LED Cube Kit

From the
 article "Build
 the 3D LED
 Matrix Cube"
 as seen in the
August 2011
 issue of
Nuts & Volts Magazine.

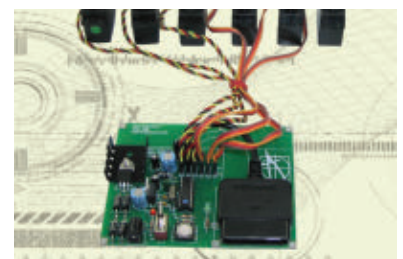


This kit shows you how to build a really cool 3D cube with a 4 x 4 x 4 monochromatic LED matrix which has a total of 64 LEDs. The preprogrammed microcontroller that includes 29 patterns that will automatically play with a runtime of approximately 6-1/2 minutes. Colors available: Green, Red, Yellow & Blue. Jig and plastic cases also available.

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	Unit	Data	Unit	Data	Unit	Data
Rated voltage	V	24	V	24	V	24
No load speed	RPM	28.3	RPM	35.2	RPM	35
No load current	A	0.61	A	1.06	A	1.18
Continuous operation	Speed	RPM	RPM	32.7	RPM	32.1
	Torque	Nm	Nm	21.142	Nm	39.131
Maximum output power	W	23.64	W	144.58	W	262.66
Resolution	Step/turn	304,000	Step/turn	502,000	Step/turn	502,000
Gear ratio	-	304	-	502	-	502
Backlash	arcmin	3.5	arcmin	3.5	arcmin	3.8
Interface	-	RS-485 / CAN	-	RS-485 / CAN	-	RS-485 / CAN
Operating temperature	°C	5~55	°C	5~55	°C	5~55



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THIS MONTH:

Nice STEMs!



THE STEM KIT FROM ROBOTIS.

One of the things we love about robots is that they are such perfect teaching tools. It is no accident that robots have become essential in curricula ranging from high school to top engineering universities — robots are the ultimate interdisciplinary project that can bring everything from basic formulas to sophisticated programming to vivid life. There have been many impressive entries into the educational robotics field, and this month we have the pleasure of presenting one more: the Bioloid STEM kit from Robotis.

The STEM kit promises to blend Science, Technology, Engineering, and Mathematics — all part of a balanced academic diet. We were particularly intrigued by the kit's promise of a comprehensive robotics curriculum. Did the STEM kit blend all of the disciplines it boasted? What fresh and new ideas did it have to offer to the educational robotics arena? Can you really make a well-balanced robotic motorcycle with something humbly labeled as the mere Standard kit? The answers to these questions and more lay ahead.



THE AX-12W DYNAMIXEL MODULE.



AN INDIVIDUAL IR SENSOR.

Waiting for Superbot

Robotis is the company behind Bioloid — a modular humanoid we experimented with in the January 2007 issue. This new kit declares itself to be the Bioloid STEM kit, so we expected a level of polish similar to the humanoid we found refreshingly less tedious to build than many of its bipedal brethren.

The meticulously designed Bioloid components contained little cutouts to hold nuts and screws, and was overall less fiddly than some other humanoid kits that sometimes left us struggling to

position tiny screws into tiny unadorned holes. Even with these pleasant design features, one might wonder if the folks behind a kit as complicated as the Bioloid could make something suitably accessible for complete novice roboticists.

Keep in mind that Robotis is also the company behind the whimsical and accessible OLLO bug kit. We first worked with the OLLO bug in the April 2009 issue, and the intrepid arthropods resurfaced in the March 2012 issue. Both times, the bugs proved to be superbly accessible kits that showcased super cool mechanisms that were buildable, even by the greenest novice.

With this sort of family background, we were excited to dive into the STEM kit. The compact box packs a surprising amount of robot, and the plethora of parts gave an exciting preview of what was to come. The Standard kit contains two motors, or rather AX-12W Dynamixel modules to be precise. The AX-12W is one of the smaller members of the Dynamixel family, but it sports the same impressive gear ratio of 32:1 and a no load speed of 300 rpm. The STEM kit also includes a nice set of sensors.

A funky T-shaped circuit board is home to numerous IR transmitter and receiver pairs. It also comes with three individual IR sensors.

The STEM kit uses the same brain as the Bioloid — a CM-530 module. All of those electronic bits are wired together with motor and sensor cables that come in a variety of sizes. To satisfy its hunger for power, the kit comes with eight holders for individual AA batteries. We are used to seeing battery packs with most kits nowadays, and the AA battery holders seemed like a bit of an odd throwback. We would soon learn, however, that every design decision in the STEM kit leads to great teachable moments.

The rest of the box was filled with structural parts. The basic building blocks of the STEM kit recall those of the OLLO bugs. The basic panels have a pattern of holes that come in two sizes: small holes for screws and large holes to accommodate rivets. Plastic rivets were the fastener of choice for the OLLO bug, and we were impressed that the unassuming devices were effective.

The rivet fasteners are comprised of two parts: a core with an appearance reminiscent of a dull nail and a slotted casing. The core slides into the casing and when pressed down completely, it can hold panels together snugly. The kit even comes with two tools to aid in construction: a small Philips head screwdriver and a tool designed to aid in removing the rivets.

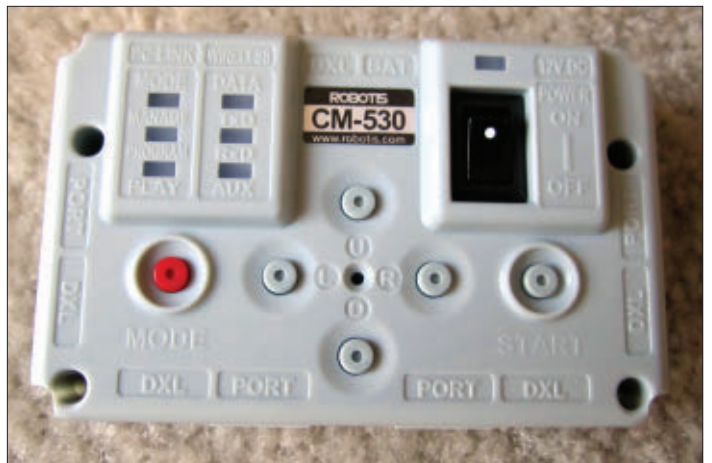
A few details about the structural bits stood out to us. First, the base plates and other panels were labeled with a grid that identified the dimensions by numbers and letters. Even though counting to 10 is easy enough, a quick look at the edge of a panel is a much more convenient way to confirm that you have the right piece. Also, each bag of screws and nuts is actually labeled with the part number. Most kits do this, but we've come across some that don't. So, we like to give kudos when the kit designers endeavor

to make things as easy as possible.

Our one complaint as far as the organization of the parts is that all of the rivets are grouped together in one bag. For the most part, though, this isn't too much of a hassle. The rivets conveniently come in four easy to distinguish colors: yellow, black, white, and gray. The one snag is that the most common rivet is the gray variety, and they come in two sizes: regular and large (fortunately, just



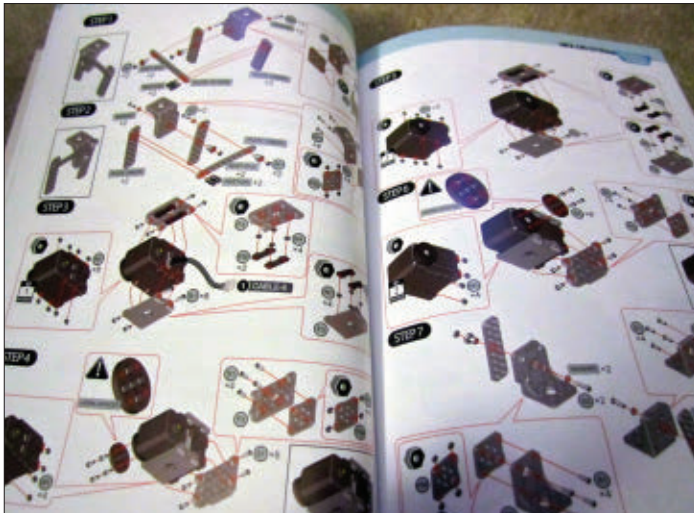
A PLETHORA OF PARTS.



THE CM-530 BRAIN.



TOOLS OF THE TRADE.



SPATIAL REASONING.

as in a movie theater, there is no small). Sorting through the gray rivets to find the required size is not terribly vexing, but stood out because of the otherwise impeccable organization.

An Education

Now that we had sorted through all of the physical components of the kit, we thought it was a good time to have our orientation to the STEM curriculum. The Standard STEM kit comes with two substantial books dedicated to the curriculum. Each book contains numerous robot designs buildable from the Standard kit, and each project is organized into three phases: the basic phase, the applications phase, and the problem-solving phase.

The basic phase includes a nice introduction to the focus of the project — whether it's understanding the idea of a program as a set of sequential steps, adding sensing capability to your robot, or appreciating the physics of balance. The entire curriculum is copiously illustrated with whimsical cartoons that bring even the most basic physics

lesson to life, and leafing through the book hardly feels like trudging through a dry instruction manual.

Because one robot design is useful for a range of lessons, the basic phase also includes building the basic bot. We thought the very first project would be a great way to get a sense of the kit, so we set about building a buggy.

The building instructions are presented as isometric drawings — much like instructions familiar to any kid that grew up playing with LEGOs. The first lesson of the STEM kit is about the nature of a simple program — a set of orders that the robot follows in sequence. In a nice interactive touch, the STEM lesson encourages new roboticists to first list things that work in sequence, like cups coming from a dispenser and staples coming from a stapler. It's easy to envision the same teaching process implemented in a classroom — the teacher encouraging students to write a few answers down, share them with the class, then move on to the real excitement of building the robot.

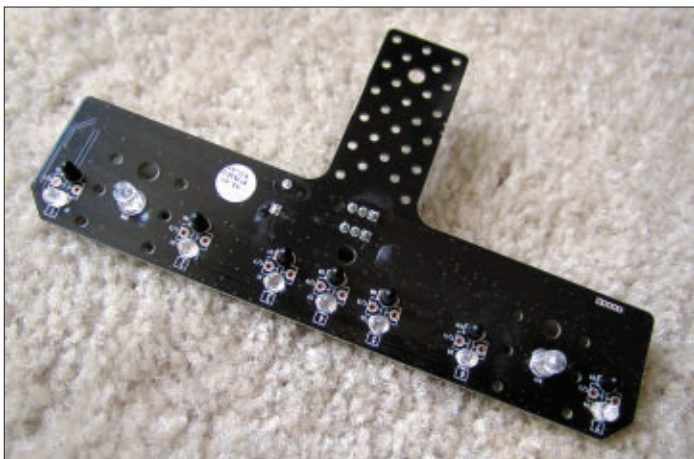
The manual includes some helpful caveats about checking the orientation of certain parts when putting things together, and there is a nice listing of all of the parts needed for the upcoming build. With those last bits of advice, the step-by-step construction instructions ensued. The basic buggy is a very straightforward vehicle disposed of in 15 painless steps. It's a direct drive bot with two wheels in the back and a caster in the front.

The primary mentor for our high school FIRST team was our dad and — given his background doing the wiring for race car engines — an appreciation for good clean wiring was instilled in us with every season in Robot Central (for those halcyon days, check out the September to December 2004 issues of *SERVO*). Given that history, we are always interested to see if robotics kits are cognizant of the virtues of clean wiring. We were particularly interested to see what kind of solution the STEM kit had in mind, especially because the presence of six individual battery holders meant six individual wires.

The solution came in the form of the parallel power board — a small circuit board that sported eight sockets: six for the battery wires, and two options for the battery cable that went to the brain. One option was for 6V and the other was for 9V. The parallel power board was a reasonable way to keep the wiring clean, and it offers a great teachable moment on the design and implementation of parallel circuits.

Program of Concentration

With the construction of the bot sorted out, the last step in the basic phase was to program the bot for the first time. The STEM kit is programmed using the RoboPlus software program. In a welcome display of modern sensibility, the STEM kit does not come with a software CD. Instead, the software is freely downloadable from the Robotis website. The robot also comes with a USB cable which seems like an obvious choice, but is not as obvious as



AN IR ARRAY.

you might think (check out the July 2009 issue for more on this vexing mystery).

The Robotis website offers a plethora of sample programs (or “tasks” in RoboPlus lingo). Downloading the first sample task is quick and painless; we were then ready to see if we made our first passing grade with the STEM kit.

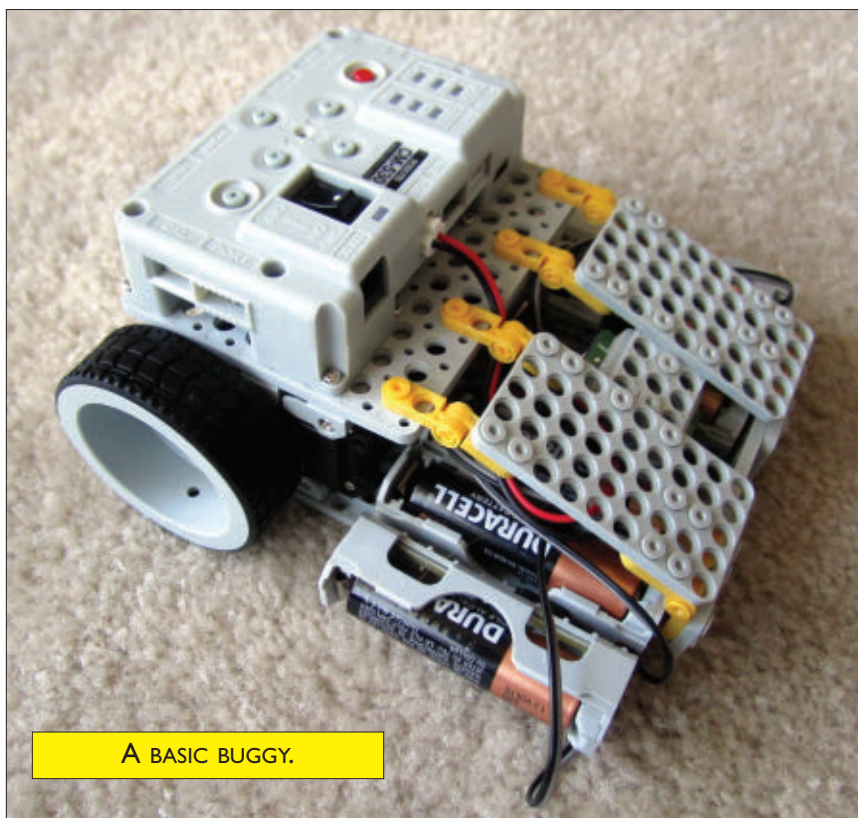
The sample program for the first lesson simply has the robot follow directions according to the way directional buttons on the CM-530 brain module are pressed. Seeing the robot buzz to life for the first time was rewarding as always. That’s one of the reasons we think that robots are such great teaching tools. Seeing a little machine that you put together come to life — no matter how simple — is always inspiring. It’s exactly the kind of pick-me-up needed before diving into our next lesson — programming.

Building and wiring up a robot has always seemed a bit less intimidating than programming. Most kids have played with LEGOs or toy cars, so the parts that go into a robot don’t seem entirely alien. Programming — on the other hand — is usually entirely unexplored territory for novice roboticists. The STEM kit, however, has come up with one of the more elegant introductions to programming that we have seen.

The first lesson about sequential commands is meant to give new roboticists a sense about what a program does — it gives a robot a set of instructions to follow one after the other. The next lesson — and the beginning of the application phase — is programming the robot. The curriculum begins with some flowcharts to explain the logic of the target program — a program that stores five button commands before executing them. Then, the manual throws actual program syntax into the mix. While this might seem like jarring immersion therapy to students, we think it’s a great way to take the plunge into programming.

The manual confronts a chunk of code, but breaks it down and explains what every piece of syntax means. It’s a bit more intense than the traditional “Hello World” introduction to code, but we think the positive reinforcement of seeing the robot obey a sequence of commands is worlds more rewarding than some unassuming text on a screen.

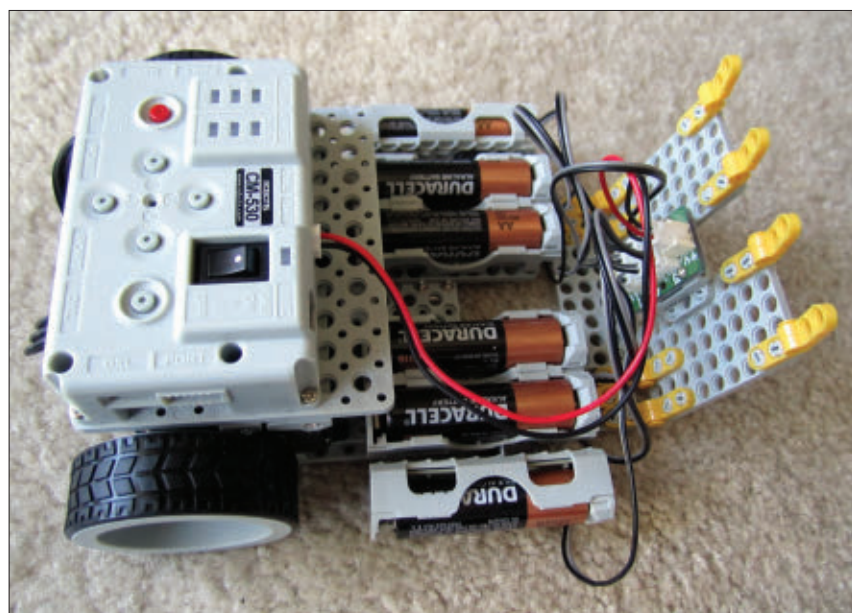
The syntax of RoboPlus is very much like C syntax, and the first lesson presents students with some loops, case functions, and some conditional constructs. The interface highlights each piece of syntax in a distinct color, making it as easy as possible for



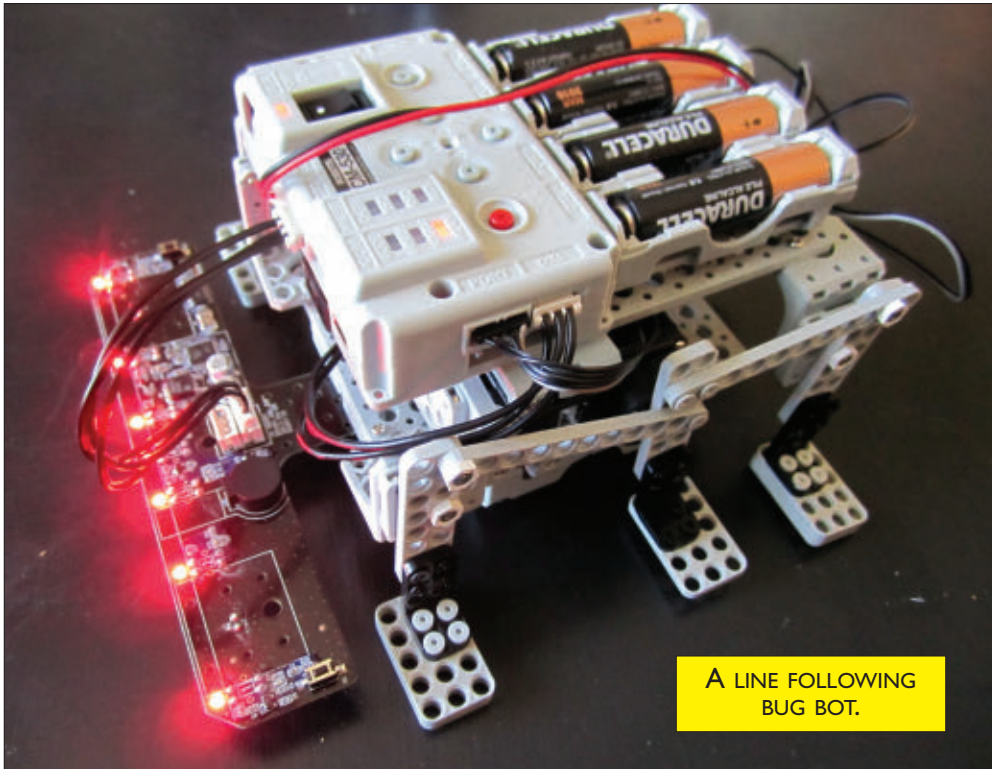
A BASIC BUGGY.

students to follow along.

Once we downloaded the program, we were at the end of the applications phase. Now it was time to move on to problem solving, and the curriculum offers a host of fun tasks for students to complete with their lively bot. The tasks range from obstacle courses to word games, and the curriculum demonstrates that there is plenty of learning to be had even with the most basic buggy design.



WIRING UP EVERYTHING FOR THE FIRST TIME.



RECOMMENDED
WEBSITE

Robotis
www.robotis.com

plenty that were eye-catching. The Standard kit offers designs ranging from electronic pianos to tread welding tumblers to combat bugs to balancing motorcycles. We thought that the bug would make a good next choice, because we always love to see an elegant walking robot design that powers six legs with two motors.

The walking bug design is actually quite reminiscent of the OLLO bugs, which also power six legs with two motors. This feat is accomplished by a clever four-bar linkage design. With Evan's mechanical engineering background, we're always fans

of cool mechanical designs (particularly four-bar linkages; check out the November 2012 article for more on that). While a six-legged walking insect might seem like a difficult design, we think it is an appropriate design to slot into the curriculum immediately after the basic buggie. Switching from wheels to legs is a great way to keep things fresh, and the design is a nice notch up in difficulty without being overwhelming.

We also wanted to try out the bug design because it used the IR array for line following. The OLLO bugs were impressive line followers in their own right, so the STEM bug had six big shoes to fill. The IR array is very easy to hook up – one cable from the array to the brain is all that's needed. One design feature of the array that we love is the presence of red LEDs to give some immediate visual feedback. When the sensors see a black surface (like the line guiding your way around the track), the LEDs beam a bright red. We think this is a great touch when you're dealing with IR sensors. It can be hard for students to get excited about using sensors where all the action is essentially invisible, so having some visible reinforcement is a nice way to stay motivated.

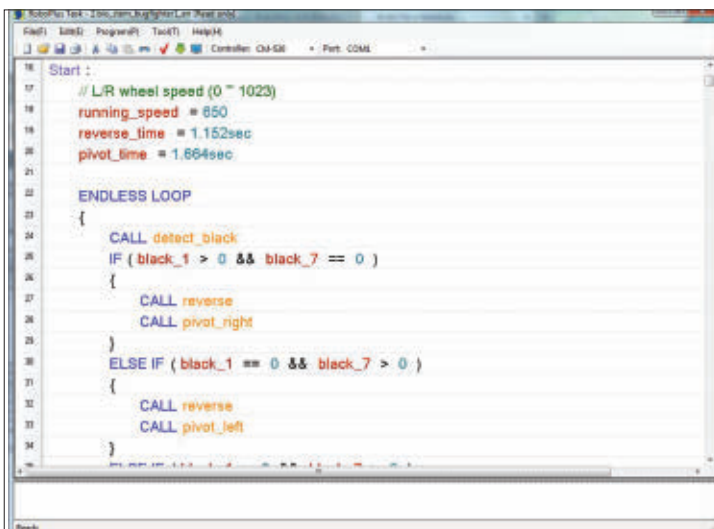
The line following bug has a sample program available on the Robotis website, and after a quick download we had an arthropod that was dutifully marching along like a good worker ant. The curriculum then suggests turning your worker into a soldier, and has a nice little discussion about combat robots.

Our inner Gandhi won out, and we dismantled the bug in favor of something more nonconfrontational. Now that we had disassembled two bots, we could say with

School of Bot

With that, we had arrived at the end of the first chapter. It seemed like we had already covered a midterm's worth of material, but this was just the tip of the educational iceberg. The Standard kit alone came with two books that contained seven chapters full of lessons and robot designs.

After spending some quality time with the basic buggie, we wanted to test out a few other designs, and there were



PROGRAMMING WITH THE ROBOPLUS SOFTWARE.

confidence that the rivet tool (which works a bit like the back of a claw hammer) is a quick and painless way to pave the way for a new design. Our only concern is that the rivet tool itself is made of plastic, so we were a bit apprehensive about its prospects for long term durability.

This apprehension would be a perfect teachable moment regarding material hardness. For all we know, the tool is a step or two up from the rivets on the Rockwell scale, and we never had any problems with it during our numerous disassemblies.

For our final exam, we wanted to build the balancing motorcycle. By working through the design for it, we finally realized why the kit favored individual AA battery holders to a more traditional rechargeable battery back. The individual packs could be distributed anywhere around the robot, allowing you to make strategic placements for weight distribution purposes or to achieve a sleekness that might not be possible when saddled with a big block of a battery.

The header board for the battery packs includes sockets labeled both 9V and 6V, meaning that the robot could get away with six or four AA batteries. With that simple addition of the extra socket on the battery header, the STEM kit creates another teachable moment that encourages roboticists to take a step back and think about power requirements. By positioning the batteries low on the bot bike, the design had a low center of gravity and balanced as well as a Flying Wallenda.

Report Card

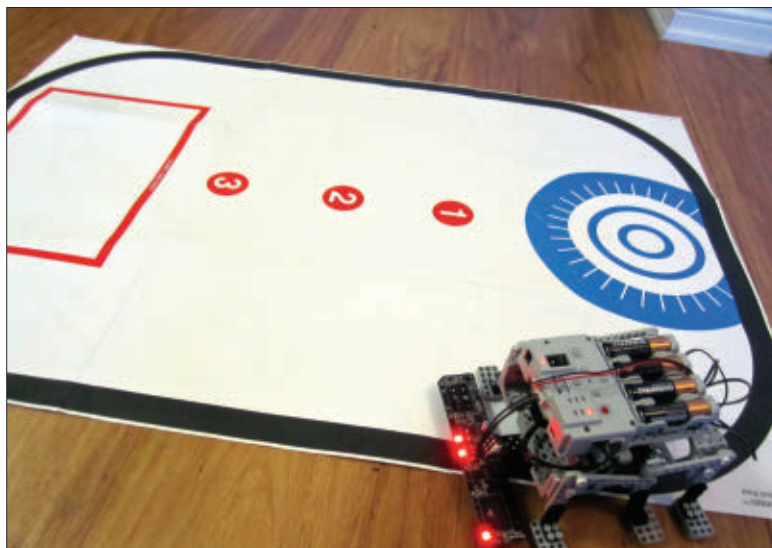
After building three designs, we felt like we had a good sense of the kit. Overall, we were extremely impressed with the curriculum that it came with. The numerous lessons did indeed focus on particular applications of Science, Technology, Engineering, and Mathematics, and the range of designs possible with two motors could fill up far more than a semester's worth of class time. The curriculum is well written and well paced, and it's something that would seem equally at home in a formal classroom setting or on someone's own time for independent learning.

The STEM kit, however, is not perfect — but no kit is. As any roboticist knows, you always learn so much more from unexpected problems and

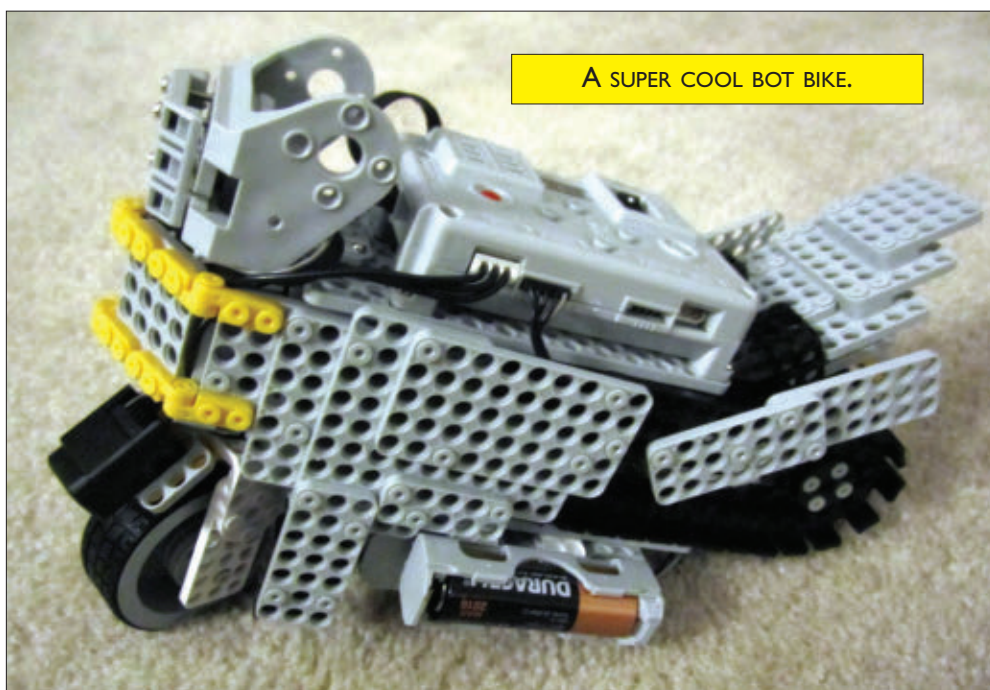
setbacks than anything else. That's when the real problem-solving kicks in, and the instances of difficulty we encountered when working through the STEM curriculum were all great teachable moments.

When some of the parts don't seem to fit quite right, that's a great opportunity to talk about manufacturing tolerances. When it seems like you need more than two hands to hold some slippery pieces together, that's a springboard for a discussion about design-for-manufacturability.

Everything about the STEM kit is geared towards getting students excited about math, science, and engineering, and for that assignment we give the kit an A+. **SV**



LIKE AN ANT FOLLOWING A TRAIL OF FOLIC ACID.



A SUPER COOL BOT BIKE.



Then and NOW

Robots Evolve into Today's Bipedal Humanoids

by Tom Carroll

Just as man's ancestors began to walk on two legs, robot experimenters decided over a decade ago that a bipedal humanoid robot was the holy grail of robotics. Science fiction movies always showed robots as two-legged walking creations. Of course, before computer graphics imaging, movie producers had to use human actors in robot suits to portray robots on the screen. The earliest bipedal robots used a shuffling gait wherein each of the robot's feet never left the floor, but just slid on one foot and then the next. Another walking method used two "U" shaped feet that always kept the robot's center-of-gravity supported. Once the advanced walking and balance mechanics were solved and gyros and accelerometers dropped in cost, the sky became the limit for experimental humanoid robots.



FIGURE 1. Vision of a DARPA robotics challenge.

DARPA Promotes Humanoid Robot Development

The Defense Advanced Research Projects Agency (or DARPA) has long been in the forefront of advanced robotics development. Hang a couple of million dollars of incentive in front of any talented group, and creative juices begin to flow. After the successes of its several autonomous full-sized Grand Challenge road vehicle contests, DARPA has now turned to the development of life-sized humanoids.

The DARPA Robotics Challenge (or DRC) requires that the contestant's entries drive a standard human-sized

utility vehicle, travel across and through rubble, open and close standard human doors, manipulate power tools to break through concrete, locate and replace a large water pump, and even climb ladders. The goal is not to prove that robots can do the same things that humans can, but to advance robotics technology to the point that humans can be spared the inherent dangers incurred in future disaster scenarios.

Figure 1 shows an imagined scenario from *Electronics Products Magazine* of two robots cleaning up a disaster situation. The green stuff pouring down is just a visual image of some of the hazards that clean-up teams face when responding to disasters. Radiation, toxic materials,



FIGURE 2. Boston Dynamics' Atlas for DRC.

explosives, falling debris, and fire are some other hazards.

Figure 2 is a depiction of Boston Dynamics' Atlas humanoid entrant

into the DRC competition. Teams have from October 1, 2012 until the end of 2013 for the first phase of the contest, and a year later to complete the second phase. Teams in Track A will develop both the robot's hardware and software for DARPA funding, whereas teams in Tracks B and C will develop control software with and without DARPA funding. Teams in Track D will develop a robot's hardware and software at their own expense. All will be eligible for prizes varying from one to three million dollars, depending on the Track level and support requirements. Some really great robot designs should result from this competition.

Multi-legged Robots Evolve into Bipedal Humanoids

Experimenters had long built multi-legged robots such as quad and hex crawlers, and these robots are still very popular. **Figure 3** shows a hex-legged robot called the Mini Hexapodinno made by Innovati. It was the hit at RoboGames 2011. The tiny Hexapodinno uses micro servos and barely stretches 12 inches with legs fully extended, but it can perform many tricks. I spent a lot of time watching folks from Kowatec (the local reps in San Jose, CA) put the personable little crab-like robot through its paces.

The KHR-1 humanoid bipedal robot shown in **Figure 4** made by the Japanese company Kondo back in

FIGURE 3. Innovati Mini Hexapodinno.



June 2004 was one of the first kit bipedal robots available to hobbyists. The design was improved through several models and the more advanced KHR-3 is shown in **Figure 5**. Most of these were sold in Asia and a few made it to the US. Walking robots rapidly became the best selling robots for hobbyists.

The Korean radio control company, Hitec debuted the popular Robonova-I the next spring, and it soon became one of the most popular robot kits. Robonova originally sold for over a thousand dollars but was 'the' robot to have and program. The Hitec robot looked similar to the KHR-1 but had much better joint brackets with special servos and a very sleek design. It soon became the humanoid robot of choice for experimenters.

Figure 6 shows one of the martial arts movements of the Robonova 1. Looking closely at the outside of the right leg, you can see wires from each of the servos in a bundle, running up to the servo controller. The cable bundles become progressively larger as they run upwards with more servo leads in the bundle.

Figure 7 shows each of the 16 servo connections lying out and disconnected from the controller

board that has the capacity for 32 servos. Having each servo's control leads running to a central controller board was perceived as a potential

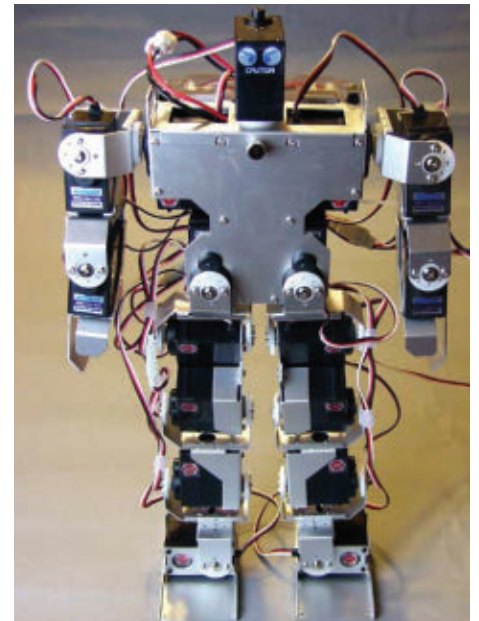


FIGURE 4. Kondo KHR-1 robot.

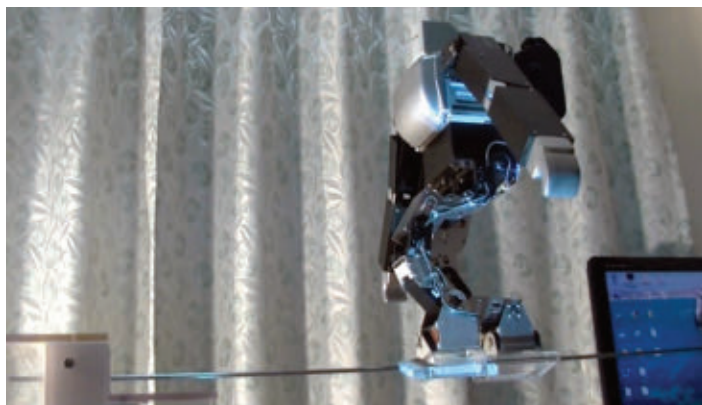


FIGURE 5. Kondo KHR-3HV robot on a tightrope.



FIGURE 6. The Hitec Robonova 1.

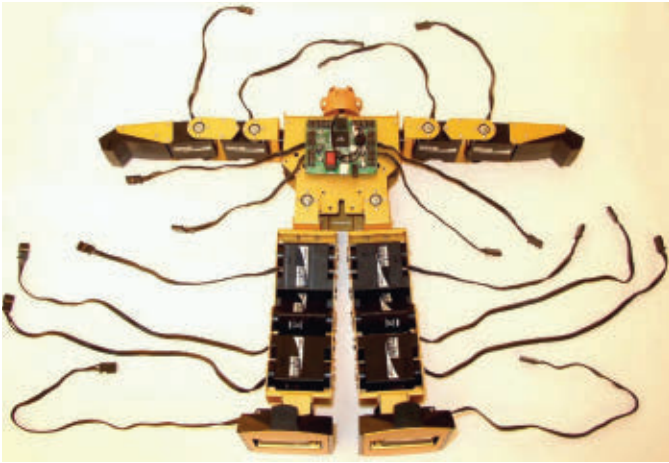


FIGURE 7. The Robonova with its servos disconnected.



FIGURE 8. The Hitec HSR 8498HB robot servo.

problem when many servos in a row needed to be controlled from a single control source.

The special HSR-8498HB robot servo shown in **Figure 8** was custom designed for the Robonova 1. It is different from standard servos in several ways. Besides having 103 oz-in of torque, these servos can be used in a standard configuration with a single horn attachment, or can utilize the second custom idler wheel to create sturdy robot joints that don't wobble.

The idler wheel is mounted on the opposite side of the servo from the horn and at the same axis, so it is perfect for solid leg and arm robot joints. The use of what Hitec calls "Karbonite" gears in the servo's geartrain allow for minimal gear

backlash in the servo's output — a very important factor in the leg servos of a bipedal robot.

Korean Companies Develop a New Servo Concept

Korea has long amazed us with so many innovative robotic products and companies. The Hubo robot and the very inventive KAIST Institute have been some of the most popular Internet robot/robotics searches for several years. Samsung's new torque-controlled humanoid robot Roboray (seen in **Figure 9**) — recently unveiled at IROS 2012 in Portugal — illustrated just how sincere Korea is in advanced robotics development.

Roboray was developed as a test platform to study bipedal locomotion using torque-controlled joints. The robot is a bit smaller than an average human at four feet, 11 inches tall; it weighs 136 pounds. It has 32 degrees of freedom, not including its fingers. The research team will soon apply speech and facial recognition to the robot to allow it to work with humans.

The unique parts of Roboray are the knee, hip, and ankle joints. They utilize torque-controlled harmonic drive actuators and compliant tendon-driven actuators that give the robot relaxed, human-like movements. These joints can be tightened or loosened according to load and movement, to allow the robot to walk more

efficiently upright with straight knees. Previous humanoids such as the Honda Asimo must use a non-human bent knee walking posture.

Roboray can easily walk up or down a slope with straight knees and can quickly right itself if pushed from the side (much like Boston Dynamics' Big Dog military robot). This Samsung development demonstrates the company's dedication to advanced robotics and is a great example of just how far Korea has come in modern technology. Two very unique Korean experimental robot kit manufacturers — Robotis and Dongbu Robot — have created a line of unique servo rotary actuators that have changed how many robot builders construct humanoids and other robotic designs.

The Robotis Dynamixel Allows for Some Unique Bipedal Robots

Robotis was established in South Korea in 1999, and developed its first humanoid bipedal robot in 2003. In July 2005, Robotis introduced the AX-12 Dynamixel actuator and the Bioloid robot kit. The OLLO robot construction kit for children came in 2008, followed by the Bioloid Premium kit in 2009 — the same year they opened their US office in southern California. It is their Dynamixel line of rotary actuators that set the company apart from other servo manufacturers. The Bioloid



FIGURE 9. Samsung Roboray humanoid robot.



FIGURE 10. Robotis AX-12 shown with a small servo.

humanoid robot was their vehicle to display the unique characteristics of the Dynamixel actuators.

In November 2012, I covered the AX-12 rotary actuator along with many other types of servos, such as the Dongbu Robot Herkulex discussed next, so I won't go into as much detail on the basic Robotis servo. The AX-12 shown in **Figure 10** has 167 to 229 oz-in of torque, uses a cored motor, weighs 55 grams, and costs a reasonable \$55. It communicates via a TTL half duplex asynchronous serial format through a daisy-chain interconnection. It is programmable and addressable. With 300° of rotation, it has position, temperature, and speed/load voltage feedback.

It operates on six to 15 volts, though a three-cell 11.1 volt Li-Po battery is optimal. The programmable serial communications allows for a single daisy-chain cable for a complete humanoid robot or other type of robot project. Operating from 2,400 b/s to 1 Mb/s, the AX-12 can be programmed through 1,024 different positions with 1,024 different speeds and torque levels. It is these characteristics that make it an ideal robot leg or arm joint actuator for custom designs. The AX-12 is part of a series of more advanced and capable Dynamixel actuators.

The Dongbu Robot Herkulex Servo

Dongbu Robot was founded in 1999, as Dasa Technology. One of the

company's first non-industrial products was the entertainment Genibo robot dog introduced in 2007, the same year it was re-named Dasa Robot. In March 2011, it was re-named again to Dongbu Robot and is based near Seoul, South Korea. Dongbu makes a line of industrial robots, as well as professional robot platforms. Other robots in the company line are a vacuum cleaner robot, public assistant robot, and some varied intelligent mobile robotic platforms. In the same manner as Robotis, Dongbu's Herkulex DRS-0201 servo shown in **Figure 11** and the smaller DRS-0101 have proven to be the basis of their line of personal/experimental robots. The Hovis Lite and the more advanced Hovis Eco that include a covering shell are the two key robots that I'll discuss.

The basic DRS-0101 servo has 12 Kgf-cm (166.8 oz-in) of torque (their DRS-0201 has twice that), weighs 45 grams, and costs only \$36 — in line with most standard servos. Both use PID control. It communicates via full duplex asynchronous serial TTL at a max of 0.67 mbps, using a similar type of daisy-chain serial communications protocol as the Dynamixel. With 320° of rotation, it also has position, temperature, and speed/load voltage feedback. It operates on 7.4 volts with a brushed



FIGURE 11. Herkulex DRS-0201 servo.

cored motor and is also a great robot joint actuator. A furnished mounting bracket is adaptable for custom designs.

Building Bipedal Humanoid Robots From a Kit

I have had the enjoyable opportunity to build both the Robotis Bioloid Premium humanoid shown in **Figure 12** and the Dongbu Robot Hovis Lite shown in **Figure 13**. There have been some great articles on building both of these kits, so I'll just delve a bit into my own experiences.

Figure 14 shows the completed Bioloid and Hovis Lite on my kitchen counter with the Hexapodinnu sitting on a rock. The relative sizes of each



FIGURE 12. Bioloid Premium in fighting stance.

FIGURE 13A.
Hovis Lite shown
without wiring.



FIGURE 13B. Hovis
Lite in martial arts
stance.

robot and the servos used in each one are in the front of 'tool boxes' to give their respective size scale.

The kits state that the included screwdriver is all that is required, however I found the use of tweezers, needle-nose pliers, a small bench vise, and even masking tape sure made assembly easier using my 'fat' fingers.

Figure 15 shows my assembly of the Bioloid.

The furnished Phillips screwdriver is slightly magnetic, so it made it easy to pick up an individual screw or nut and place it in the required hole.

Careful reading of each small step

of the assembly is very important. The Bioloid kit manual described the assembly strictly in a series of visual black and white pictures. Sometimes I had to look over the whole page just to realize what the next step would be. The Hovis manual has more assembly pages and all were annotated in English. Their manual depicts each plastic bracket in bright green, and the Herkulex servos and the tiny mounting brackets were in black. It was sometimes difficult to clearly see the mounting of these tiny black brackets as they were mounted to a black servo. Both company's

manuals were very well printed, but I did find a few errors.

In many ways, the assembly of the Bioloid robot was a bit simpler in that there was a single size of screw that was used throughout most of the assembly process, though other sizes were used in certain areas. When the Bioloid was completed, I had hundreds of tiny metric screws, nuts, and even brackets left over.

Both of the kits are designed so several projects can be made with different configurations of the actuators/servos and bracketry. I was amazed with just how many parts are used to construct these robots. It is the sheer number of tiny fasteners and brackets that made me decide that these kits are designed for younger "adults" than me.

Things to Watch Out For

With very detailed kits, not only must you read the manual carefully but take care to identify locations, orientations, and just "where did this wire go to?" type of questions. It is very important that you verify the servo's horn position before mounting the joints to them. There are faint marks on the Herkulex servos but it was easier to verify positioning on the spline. There were a few instances of differences of a pictured green plastic part for the Hovis than what was in the kit, but it didn't matter.

There were some furnished



FIGURE 14. Completed robots and Mini Hexapodinno.



FIGURE 15. Assembly of the Bioloid.



FIGURE 16. Bioloid CM-530 ARM Cortex STM32F103RE controller.

screws that were a bit too short, but I just left out one of the plastic shims in each wrist and it worked just fine. I also found it helpful to place a tiny masking tape tag on each connected three- or four-conductor cable on both of the robots, as it sometimes became difficult to determine which wire went to which servo or sensor when the chest plate was attached to hide them.

Robot Comparison

In many ways, a direct comparison of the two robots is not fair as they have different capabilities, processors, and other factors. However, a comparison is inevitable as these two robots are the only intelligent servo bipedal robot kits currently on the market. Both robots

use a high strength plastic for the molded brackets. Both companies offered high quality castings and the nut insert's variously located holes make them very versatile. With strength close to what you might find in bent sheet metal aluminum brackets, these plastic brackets work just fine. The extra brackets, plates, and fasteners found in each of the kits allow an experimenter an almost unlimited number of different designs.

The 60 ounce Robotis Bioloid Premium has 18 AX-12 Dynamixel servos and uses the ATmega 2561 in its CM-510 controller, though I also used their newest CM-530 controller shown in **Figure 16** that utilizes the ARM Cortex STM32F103RE processor. It has a dual axis gyro, a distance measurement sensor, a wireless (IR and ZigBee) communications

controller system, and two IR object detection sensors.

The RoboPlus software is easy to use and quite complete for all the kit applications. I had a few hiccups when starting it up, but the problems were caused by a few of my mechanical mess-ups. The Bioloid has a great walking ability and is surprisingly stable. The Bioloid Premium costs about 50% more than the Hovis Lite, but the amount of information available on this robot is vast. Customer service is also very good.

The number one advantage one might find with the Hovis Lite robot is the cost. Many have called the Herkulex servos 'clones' of the more popular Dynamixels, and that may be. It's said that imitation is the most sincere form of flattery, and this robot

FIGURE 17. Hovis Lite toolBox case.



noDNA



FIGURE 18. Hovis-Herkulex ATmega 128 controller.



FIGURE 19. Bioloid and Hovis Lite.

is worthy of praise. The tool box case shown in **Figure 17** is great for keeping all the parts in one location during assembly, and is ideal for carrying the completed robot around afterwards. The Hovis Lite comes in red, blue, yellow, as well as the green (shown) and is about 13.7 inches tall and weighs 1,450 grams. The standard degrees of freedom are 16 Herkulex servos, but it can be expanded to 24. The onboard DRC controller shown in **Figure 18** uses an ATmega 128 microcontroller and runs DR-Sim (3D Simulator) and DR-Visual Logic (Task Editor). The DR-Visual Logic takes a bit of careful study, but should be intuitive to those with a C programming background. The DRC controller is capable of running several system checks and tests on the robot, and LEDs assist the user in determining and correcting problems.

Dongbu also includes a full-function handheld IR remote control. It is powered by a hefty 7.4V 2,800

mAh Li-Po battery. It includes a PSD distance sensor that allows the Hovis to sense and easily avoid obstacles. A gyro is available at extra cost, as well as ZigBee communications. Dongbu Robot has introduced the Hovis into Korean schools and is planning an introduction into US and European educational systems soon.

Final Thoughts

I've had a real blast building, programming, and operating both of these robots. Either of these humanoid machines would make a great addition to a robot collection. If cost is a concern and you still desire great performance, I'd choose the Hovis Lite.

This robot can be easily upgraded with an external shell to form the Eco model, or you can purchase the 20 DOF Eco for \$260 more. Go to **dongburobot.com** to see their products and distributors.

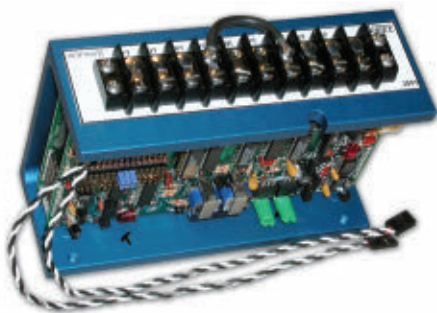
If you really want a bipedal humanoid robot that has been around for a decade and has a lot of university, military, and advanced users, then I'd choose the Bioloid Premium at **robotis.com**. Its cost is about 50% higher than the Hovis, but it's worth it, in my opinion.

The Dynamixel line has servo actuators to fit all user requirements for robots, robotic platforms, and separate robot arms. Both the Dynamixels and the associated Robotis robots have a large following here in the US and across the world.

I encourage you to read more about both of these robots and compare them yourself. **SV**

I'd like to thank Jinwook Kim (Jinux) from the Southern California office of Robotis, and Daniel Hwang of Dongbu Robot — soon to transfer to the US office. These gentlemen were most helpful to me and tolerant of some of my inane questions.

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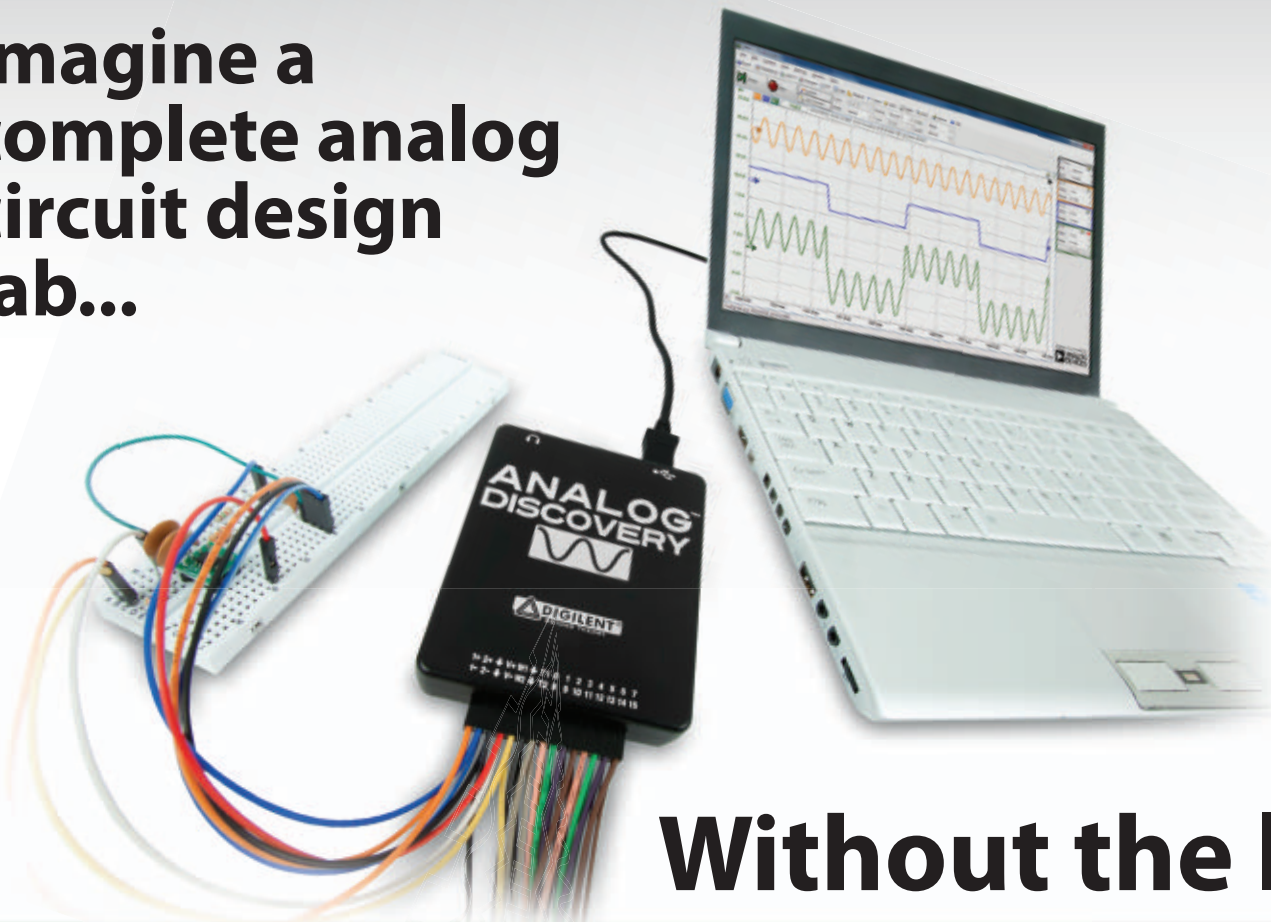
	DRS-0601	DRS-0602	DRS-0401	DRS-0402	DRS-0201	DRS-0101
Size	56mm(W) X 35mm(D) X 46mm(H)		56mm(W) X 35mm(D) X 38mm(H)		45mm(W) X 24mm(D) X 32mm(H)	
Weight	145g		123g		60g	45g
Input Voltage	9.5 ~ 14.8V DC				7 ~ 12V DC	7.4V DC
Stall Torque	77.0kgf.cm@14.8V / 62.5kgf.cm@12.0V		52.0kgf.cm@14.8V / 43.1kgf.cm@12.0V		24.0kgf.cm@7.4V	12.0kgf.cm@7.4V
Max. Speed	0.164s/60° @14.8V		0.162s/60° @14.8V		0.147s/60° @7.4V	0.166s/60° @7.4V
Operating Angle	320°, Continuous Rotation	720°, Continuous Rotation (Built-in Speed Controller)	320°, Continuous Rotation	720°, Continuous Rotation (Built-in Speed Controller)	320°, Continuous Rotation	
Resolution	2048 Steps	12960 Steps	2048 Steps	12960 Steps	1024 Steps	
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